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Performance of Generating Plant: New Metrics for Industry in Transition

World Energy Council

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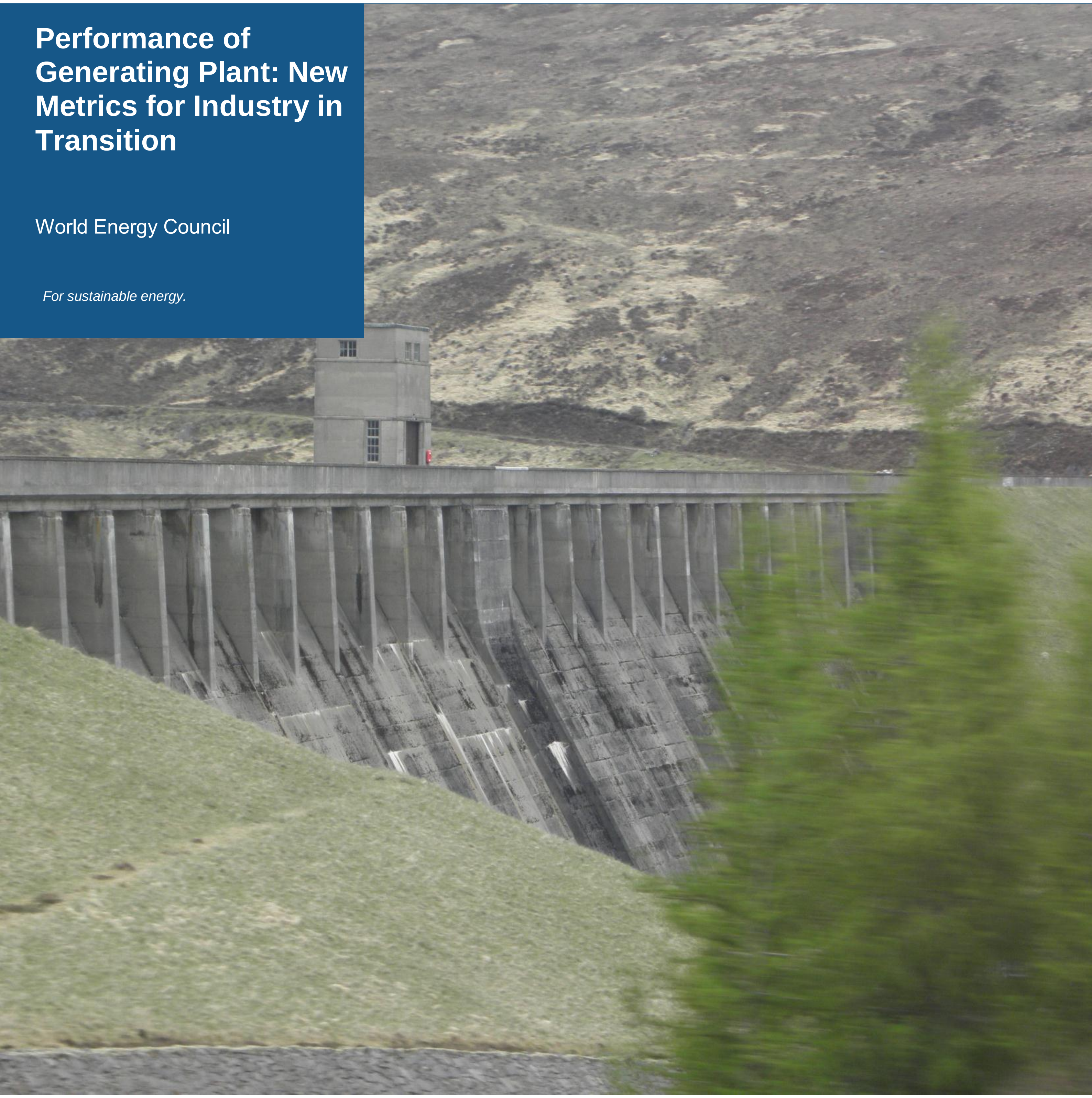

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Contents

Performance of Generating Plant: New Metrics for Industry in Transition

1. Measuring and Improving Power Plant Performance within an Increasingly Complex Electricity Supply Sector *Work Group 1, Chair: Scott Stallard, Black & Veatch, USA)*

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

3. Nuclear Power Generating Units

4. Performance Indicators for Renewable Energy Sources

5. Technology Transfer : How to Make it Happen

...

2

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Performance of Generating Plant: New Metrics for Industry in Transition

Introduction

This report was produced by the four Work Groups of the World Energy Council's Committee on the Performance of Generating Plant. The report is also available for downloading on the WEC website at www.worldenergy.org.

1. Measuring and Improving Power Plant Performance within an Increasingly Complex Electricity Supply Sector

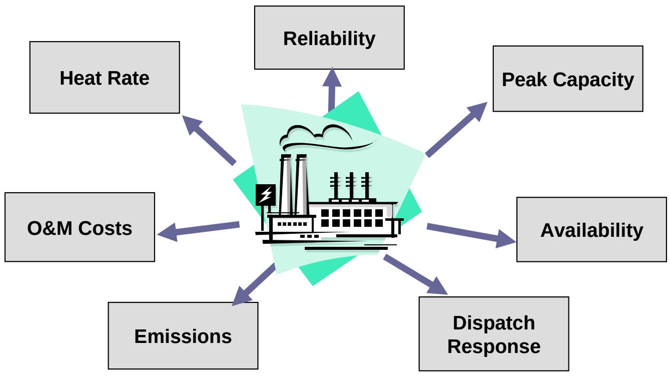
Work Group 1,
Chair: Scott Stallard, Black & Veatch, USA

Since the 1970's, the World Energy Council's Performance of Generating Plant committee (WEC PGP) has collected power plant performance statistics from the various countries with the goal being to both identify means to collect/disseminate data as well as means for evaluating performance and identifying performance opportunities. This allowed the industry to evaluate reliability impacts associated with major technological segments (e.g., technology, fuel, vintage, size, etc.). These efforts have been instrumental in developing standards for sharing of data across disparate systems and operators.

During the last two decades, the electric power sector has been subject to substantial changes which included regulation and deregulation, 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 business models. 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 an eye on cost of improvement to value delivered to utility/customer?

As can be seen in the figure below, metrics for performance can be diverse depending on asset and its role in the market.

Performance Factors/Metrics



As such, best practices for measurement and analysis of performance must be altered or extended as well. Historically, efforts of the PGP Committee to develop a better means to address such issues across the wide range of power generation assets worldwide has centred on the idea 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; and 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.

Further in the report we take a closer look at the situation as it pertains to expectations of performance and performance measurements. The focus is on the United States and Europe in particular, due to the emerging importance of CO_2 and its implications for both technology and selection or definition of appropriate performance metrics.

Later on the attention turns to the topic of performance measurement, as driven by political, environmental and market realities. In this section, we analyse how to address and how to consider best 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.

Through the application of the techno-economic model developed in the last triennial period, the effects of market on value of performance improvement are compared/contrasted. This model has been updated to consider cost of carbon as an input to production cost and to bid strategy; the model is used to consider broad implications of CO_2 versus traditional financial factors.

Towards the end of the report, challenges in addressing efficiency as key performance metric will be presented. Globally, GHG emissions, cost reductions, and sustainability considerations are all beginning to target generation efficiency as a critical element of the strategy. Therefore, further analysis of efficiency metrics as key performance indicators is necessary given growing importance of CO_2 emissions.

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 scrutinised.
- **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 favourably 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.

The Committee's work indicates that the impact of mixed regulated/deregulated energy supply sector in combination with the drivers discussed above results in *increasingly divergent goals*, *objectives, and priorities* for generation asset owners. With the inception of CO_2 and other politically charged agendas, one could argue that the "value" of performance has become more complex and must be addressed in the context of both economics and environmental factors.

Many questions arise with respect to economic and environmental priorities.

- **Capital**: Where to invest? New generation or existing assets? For existing, environmental or reliability/efficiency improvement? For new, traditional or renewable generation assets? Generation vs. transmission?
- **Short-term vs. Long-term**: Major transformations potentially around the corner can substantially change the role and value of various assets (i.e., CO_2, Smart Grid, etc.) Hence, how to weigh value of short-term performance initiatives against longer-term objectives?
- **Environmental Regulation**: Clearly this is the biggest wild card offering potential scenarios that can fundamentally alter market economics, dispatch strategies, and value propositions. How to address given current uncertain picture?

United States

Unprecedented pressures are now being exerted on the US utility sector. Although such pressures come largely from the political and environmental/regulatory fronts, recent efforts of the Obama administration to fund SmartGrid initiatives under the Stimulus Act are also impacting the sector.

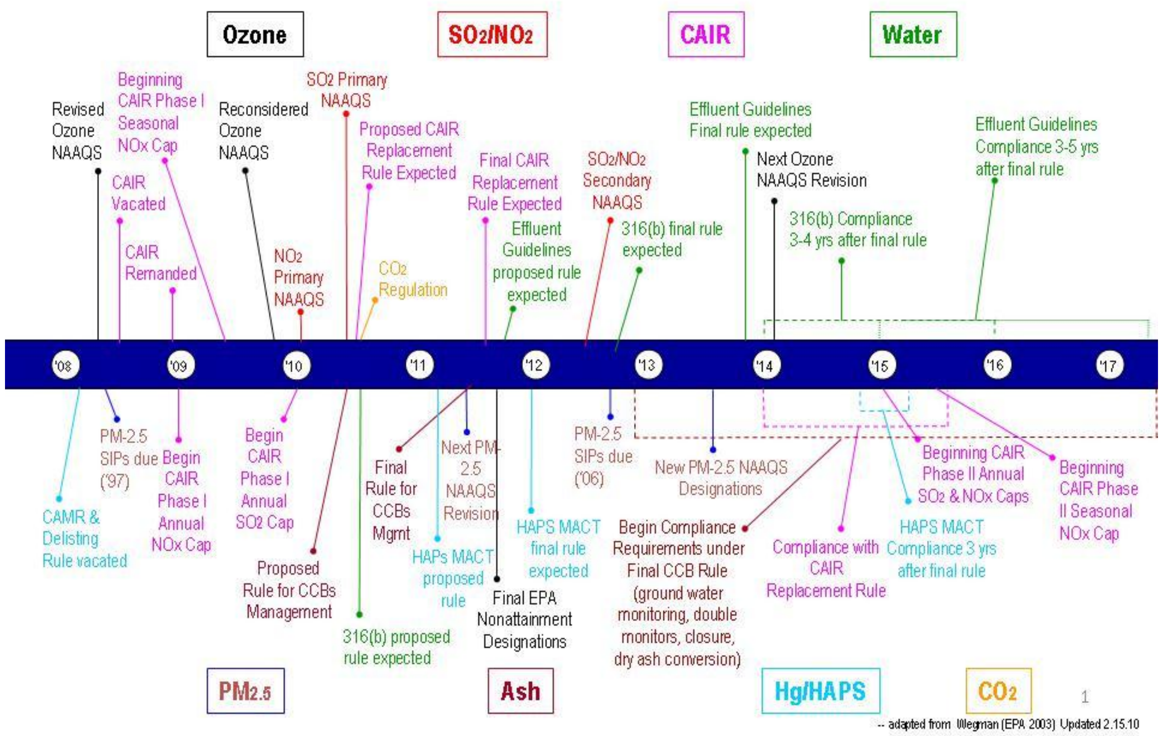
In 2007, the Supreme Court of the United States forced the Environmental Protection Agency to recognize carbon dioxide as a pollutant, potentially paving the way for the United States to "catch up" with Europe as the world continues to seek the best methodology for curtailing global CO_2 emissions.

While handling the impacts of carbon emissions world-wide will be a long term multi-pronged solution set, a more direct question, and one with slightly less political solution, is how does this gradual movement toward a less carbon intensive electrical sector impact traditional generating technologies like coal and natural gas in the near term, and how, if at all, will these technologies remain competitive in this new future?

And, it is not just carbon. Interestingly, further challenges to existing fleet are due to further pressure being exerted from EPA and environmental groups as they seek to aggressively address a wide range of environmental issues. As can be seen from the figure below, the unprecedented regulations spell expensive change for the generation sector – both in the form of additional costs/performance pressures on existing plant via implementation of new equipment as well as, in some cases, forced retirement of old generation and build-out of new cleaner generation.

utility infrastructure. This capability both supports automation solutions within the utility operation as well as the development more customer-oriented distribution infrastructure for electric utilities.

Environmental Regulatory Timeline for Coal Units



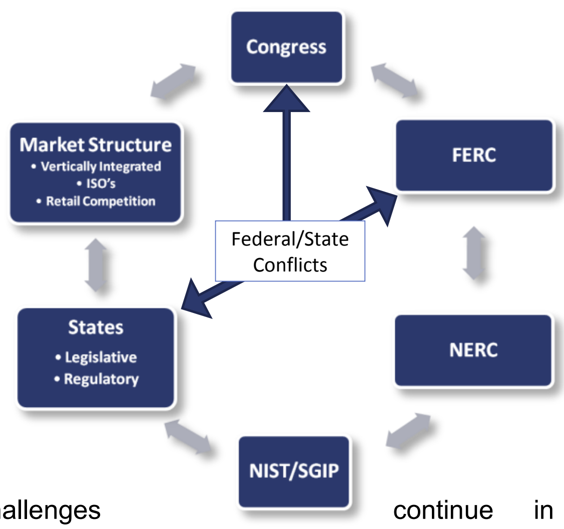
At the present time, the path forward for new generation is likely to include nuclear but be dominated by natural gas, combined cycle. One can surmise that over time, CO_2 emissions from natural gas-powered assets will also be targeted. The overall implications such changes will have on generation capability, reliability, environmental footprint, and costs are not fully understood.

Efforts to develop a "Smart Grid" target improved reliability, resilience, and flexibility of the electric grid. This modernisation consists of a telecommunication overlay upon the utility network to provide connectivity to the distributed

Interest in renewable energy continues to grow with Smart Grid envisioned as the technical enabler for allowing large scale integration of renewables, demand management capabilities, and energy storage. With growing attention to global climate change, implementation and use of renewable energy technologies is receiving support from numerous constituents in the developed countries, and is also seeing support from influential groups in developing countries. In the United States, subsidies and mandates like renewable portfolio standards (RPS) continue to provide incentives for market growth.

Larger macro issues that affect attractive and penetration rate of renewables in the US include:

- Government mandates, whether at the central or local government levels, that are forcing traditional utilities to build renewable systems.
- View that coal generation will be substantially replaced by natural gas and renewables.
- Rapid developments in technologies that are driving down costs for renewable technologies.
- Continued technological developments which are yielding more efficient devices and larger scale units improving overall system economies of scale.
- Substantial government subsidies that are allowing renewable technologies to become a logical, economic choice.



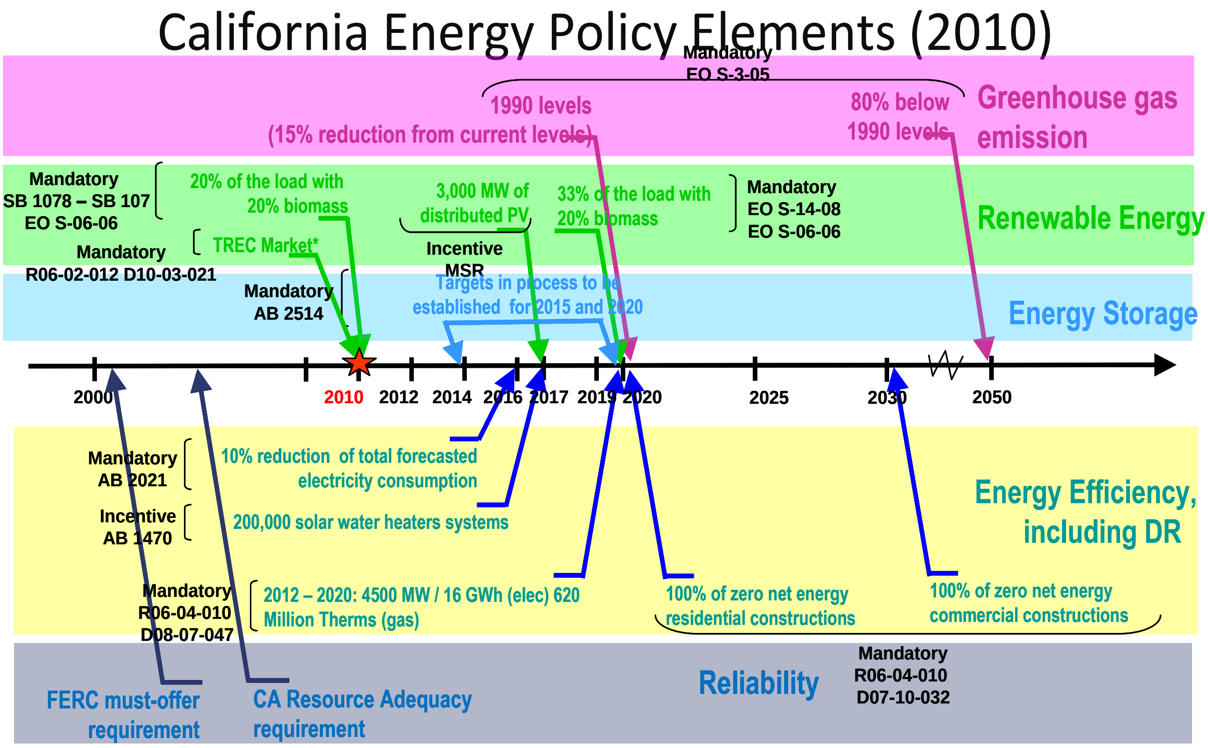
Challenges continue in the United States with respect to regulation and energy markets. As can be seen in the figure at right, US policy and enforcement is divided among federal, state, and agencies. Hence, it is often difficult to reconcile issues or address issues holistically given the number of parties involved. Specifically, federal control of transmission versus state control of distribution (and associated aspects of the Smart Grid) provides particularly difficult challenges.

As recently discussed by Suedeen Kelly, former FERC commissioner, standardized market designs currently operated under Independent System Operators (ISOs) are designed to promote competition and allow appropriate access to market for 3rd parties – given that the access can be addressed via a transmission interconnection.

She believes that, particularly, the pressure to involve and integrate 3rd party renewable generation will require aggressive action and believes that, as such, the United States may be on the cusp of developing an national energy policy centered around renewables and Smart Grid. She cites many drivers for this including:

- Green agenda under Obama administration
- Opportunity to create a new market/new commodity
- Ability to link to jobs/economic development for wind.
- Improved energy security
- Attractiveness to customer to see lower volatility on energy prices with respect to that of oil or natural gas.
- Obama's intent to advance US technology by assuring that such technology can both be built and implemented in US.

California continues to be one of the more aggressive states in terms of advancing both renewables and Smart Grid. In fact, as shown below, California energy policy is based on substantial reductions in greenhouse gases, large deployments of both renewables and energy storage, and energy demand and efficiency management.



(*) Tradable Renewable Energy Credit Market: April 2010 (with IOUs limits until 2012) **Source: EPRI**

While one can argue about the impact of stimulus spending on advancing the Smart Grid to date, Ms. Kelly believes that, under Obama, additional stimulus funding for Smart Grid will be legislated.

Europe

Actions by the European Council and the Parliament to set precise, legally binding targets for CO_2 provides the foundation for its past and current CO_2 mitigation regulations. Since 2005, the European Commission has issued directives oriented toward free trade of emission allowances across the European Union and has, so far, completed two compliance cycles. However, due to "excessive allocation" of allowances in some Member States and some sectors, the cost of CO_2 allowances has been much more modest than anticipated and CO_2 reductions lower than would have been realized with more stringent limits. Recent actions by the European Commission are more aggressive.

The "Energy and Climate Change Package" was initially put forward on January 23rd 2008, was adopted by the Council and the Parliament in December 2008.

At the heart of the package are three commitments to be met by 2020[1]:

- To reduce greenhouse gas emissions by at least 20% with an offer to go further and commit to a 30% cut in the event of a satisfactory international agreement being reached.
- To ensure that 20% of final energy consumption is met with renewable sources.
- To raise energy efficiency by 20%.

Amendments to Directive 2003/87/EC provides a clearer definition of the combustion installations to be covered by the directives with the scope expanded by including CO_2 emissions from petrochemicals, ammonia and aluminum plus new provisions for N_2O emissions; the overall coverage of the EU ETS will roughly increase by

[1] Dechamps, Pierre, European Commission, Belgium, "EU Energy and Climate Change Policies: Towards 2020 and Beyond," Power Gen Europe 2010.

up to 140 to 150 Mt CO_2.

The Directive determines the shares of the total quantity of allowances that Member States will auction.

- 88 % of the total quantity of allowances to be auctioned will be allocated between Member States in proportions identical to the proportion of verified 2005 emissions;
- 10 % of the total quantity of allowances to be auctioned will be allocated between certain Member States in the interests of solidarity and growth in the Community,
- 2 % of the total quantity of the allowances to be auctioned will be allocated between the Member States which had achieved in 2005 a reduction of at least 20 % in greenhouse gas emissions compared with the reference year set by the Kyoto Protocol

Other key aspects of the directives and related actions include:

- A "burden sharing" agreement covering the rest of the EU emissions, coming mostly from buildings and transport.
- Power generation sector generally will have to acquire 100% of the emission allowances it needs in the auctions.
- Promotion of the use of energy from renewable sources establishes an overall binding target of a 20% share of renewable energy across three sectors of electricity; heating and cooling; and transport.
- 2006/32/EC on energy end-use efficiency and energy services requires Member States to adopt a 9% indicative energy end- use savings target in 2016 and to put in place institutional and legal frameworks and measures needed to remove barriers to efficient energy end-use.

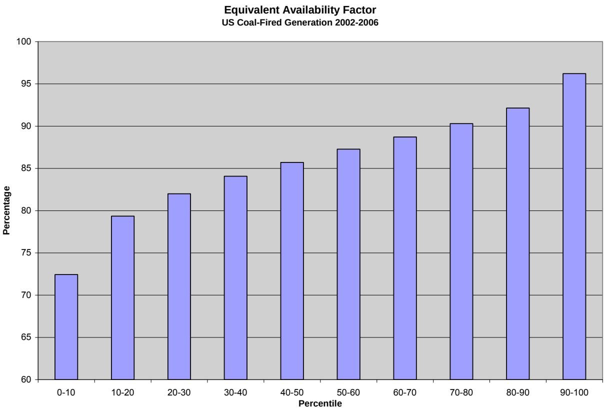
Directive of the European Parliament and of the Council on the geological storage of carbon dioxide, covers the geological storage of CO_2.

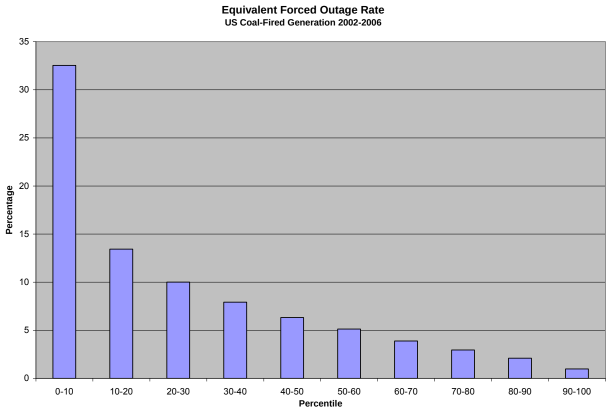
Performance Measurement – As Driven by Political, Environmental, and Market Realities

Benchmarking and other similar techniques that focus on comparison of unit performance against that of its peers remains an invaluable aid for discovering and realizing performance improvement opportunities. Benchmarking is a process used to evaluate various aspects of their 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 increasing 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 objectives, presuming adequate data availability.

Industry “best practices” often 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 following figures, the distributions are far from normal.





	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)
Bottom 25%	77.0	(8.8)	(16.5)	19.7	(11.5)	(18.0)

Continuing the Journey – Integrating Market, Environmental, and Financial Perspectives

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.

Continuing the Journey – Integrating Market, Environmental and Financial Perspectives

Benchmarking methodologies must be adapted to evaluate differences in "value" associated with different markets, regulation, and technology. The reality is that mixed regulatory, ownership and market perspectives correspond to mixed goals, objectives, and priorities for generation entities. Hence, today, one must think in strategic and economic rather than purely technical terms; this can be coupled to technical data derived from benchmarking to provide financial perspective. 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 requires one to re-evaluate 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.

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.

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?

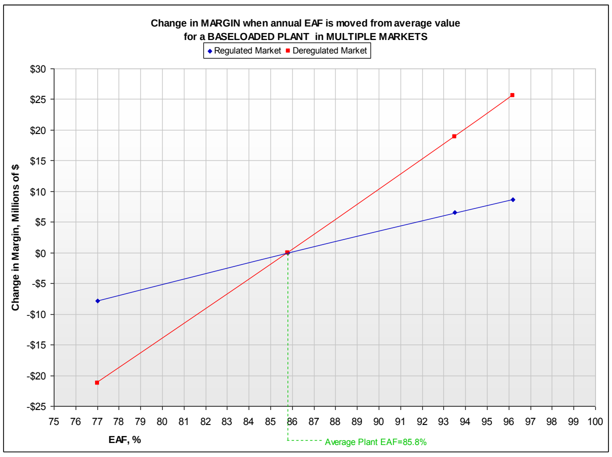
To address this issue, in 2007, the PGP Committee introduced the initial version of a spreadsheet-based tool[2] to be used to compare/contrast performance within the context of financial performance.

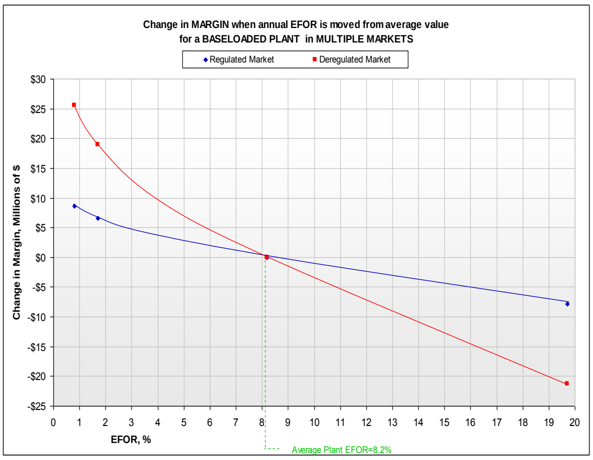
It provides a mechanism for analysing and presenting a thorough availability and economic comparison for various facilities, technologies, and market designs.

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.



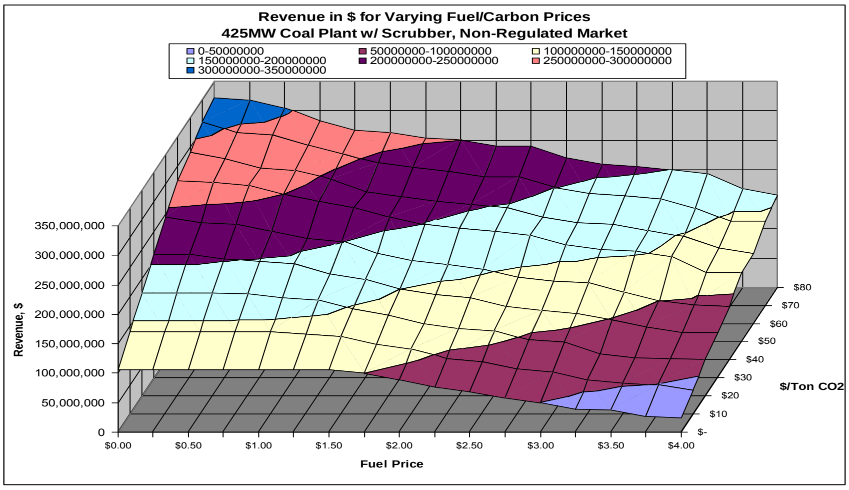


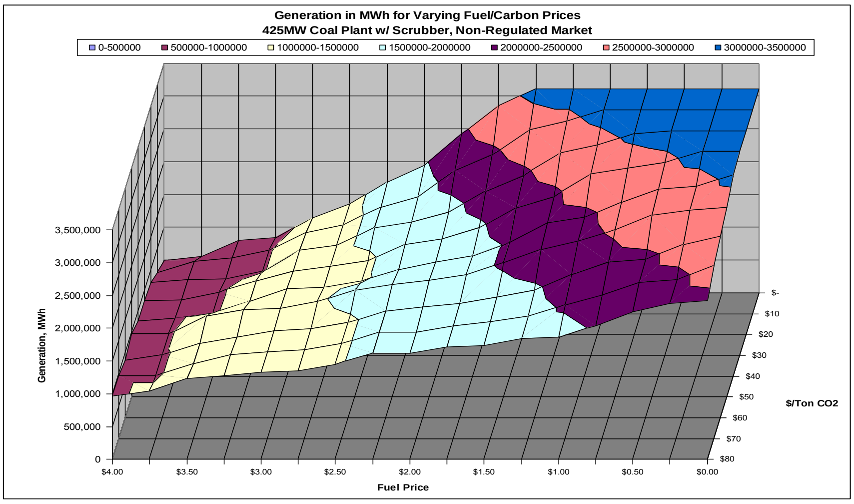
The industry's challenge is to continue to find ways to not only collect and analyze the necessary data but also to provide the framework for which to extend the analysis across markets, across technology choices, and across financial realities.

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 generation sector. 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 figures above[3], the predicted impact of a market price of CO_2 impacts each generation technology in a slightly different way.

- Generation from coal declines as fuel prices increase – simply indicative of decreased competitiveness amongst the same technology generation assets.
- For the coal based asset, increasing CO2 prices, will more or less, uniformly impact bid price for coal-fired generation as generator seek to recover the costs of CO2.
- Gas becomes more competitive on the margin at higher CO2 price, due to lower CO2 intensity and will displace more coal in base-load market.

It should be noted that strong variations in fuel prices can be far more deterministic to the fate of any particular asset because it impacts dispatch of an *individual* coal-fired generation asset, as fuel cost variations are not uniformly seen across the market; conversely, CO_2 costs impact relative viability across technology classes.

Impact of CO_2 and Fuels Costs on Total Revenue

The resulting impacts on total revenue for both coal and natural gas fired units are relatively straightforward.

As a generator experiences a higher fuel cost, their dispatch position in the queue among similarly fired competitors erodes. Thus the ability of that asset to achieve "base load" operation is highly limited as a function of fuel price. However, as CO_2 costs increase, revenue is actually predicted to increase, but largely due to the fact that a large percentage of this cost is expected to be "passed through" to the consumer.

It should be noted that the market cannot immediately materially impact the makeup of generation assets available. More precisely – although higher CO_2 costs will put pressure on coal and will generally reduce its role – in the short term, it is assumed that there are not enough existing gas assets to materially displace coal generation.

For gas generation, revenue will increase with CO_2 as gas gains both MW against coal and is able to fully recover the cost of the CO_2; assets with high-price gas supply will remain out-of-the market until CO_2 price is high enough to garner some load.

Impact of CO_2 and Fuels Costs on Variable O&M

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.

[3] 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 end that, 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.

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.

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 (CO2) and local (e.g., fuel costs) influences

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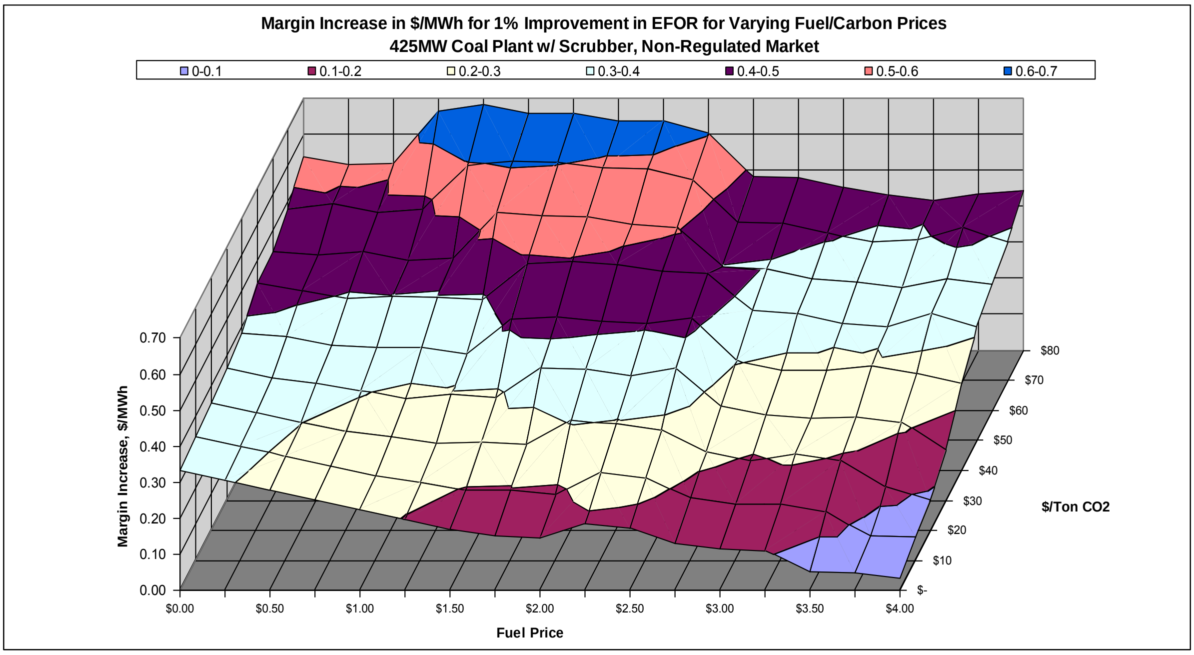
Efficiency Improvement

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 by conducting workshops, training modules, 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

This report presents an overview the PGP and its applications. It also invites all generating companies to contribute to the database so its information will be enhances and increased to aid other generators worldwide.

Introduction

The evaluation of power plant performance is one of the most important works at any power station. Without its availability records, the plant staff cannot determine ways to improve performance of the equipment and make the plant a profit-centre for the company. The causes of unavailability are thoroughly analysed to identify the areas for performance improvement. The PGP has been collecting statistical data for many years on power plant availability using WEC's global network of Member Committees.

There is no simple way to measure overall plant performance, nor is there a single indicator which could be used for this purpose. Operating conditions vary widely between the countries and regions, and in addition to high reliability, power plants must at the same time achieve a number of other objectives: economic, environmental, societal, etc. These objectives are different for different power plants, and each plant has its own particular aspects to take into account.

The increasing competition in the electricity sector has had significant implications for plant operation, and it requires thinking in strategic and economic rather than purely technical terms. This is not always easy for the global community of power plant operators, which is heavily dominated by engineers with a “technical mindset”. The need for efficient allocation and use of available resources; effective scheduling of plant activities, such as outages and on-line maintenance, greater use of analytical tools to conduct cost/benefit evaluation of proposed activities are changing the industry mindset.

These new needs, reinforced by dynamics of the ongoing change, are creating an atmosphere of uncertainty in the market. The uncertainty of meeting demand for electric power and the shareholders’ profit expectations place additional pressures on power plant operators. The challenge is both to improve the performance of the existing generating plant stock and to build enough – but not too much - new generation and transmission capacity to meet growth in demand. Old plant will need replacing with environmentally friendly generating units to provide the worldwide need for more and efficient electricity sources.

PGP IS AN “AVAILABILITY” DATABASE

The performance of an electric generating plant is measured by a group of metrics including availability, efficiency, emissions, cost and others. For a specific plant using a particular technology (nuclear, fossil steam, gas turbine, combined cycle, hydro, etc.), its design and dispatch requirements will determine its “inherent” or “theoretical best achievable (TBA)” potential performance. This TBA potential will only be attained with “perfect” Operations and Maintenance (O&M) management practices so that its equipment’s failure rate and repair time is minimized.

In actual practice for generating plants around the world, the actual achieved (AA) performance is frequently below (and often far below) its TBA values. The size of this gap, relative to other plants of its type, is a measure of the effectiveness of the plant’s O&M management practices. In fact the World Energy Council’s (WEC) Performance of Generating Plant (PGP) committee has estimated that 80% of the gap is due to “less than perfect” O&M management practices. Improvements in a plant’s O&M management practices, along with replacement of inadequate or worn-out components, can substantially reduce its performance gap, but the plant can never exceed its “design” or TBA performance without design modifications e.g. a plant with a design efficiency of 50% can never achieve a 55% efficiency unless there are substantial and costly changes in its design.

To illustrate this principle the following is an example of a typical coal-fired generating plant’s availability statistics for all megawatt sizes over a period of 2005-2009. The Energy Availability Factor (EAF) range for these 1,003 units is:

Maximum Availability:
    100%
TBA Availability:
    93.05% (top decile of peers)
AA Availability:
    Range between 0 and 100% with a median value of 86.3%. Please note that 71.4% of the unit population has its EAF between 80-89%.

The term “availability” here means the percent of energy the unit is capable of producing over any given period of time, relative to its design capacity. Availability is the resulting number after you remove all outages and restrictions due to both planned and unplanned events (except for dispatch requirements) with 100% being the maximum.

Since no generating plant can be expected to operate forever at 100% availability (unless it is in a "ready-to-operate" state but never operated), its TBA can be estimated by either benchmarking the historical availability of its peers or by constructing a Reliability, Availability, Maintainability (RAM) model. The PGP database provides a number of availability indices for benchmarking and other uses. These will be discussed later in this report.

In a similar fashion each generating plant will have its own unique design efficiency, design emissions levels, etc. as well as comparable TBA values. It must also be recognized that achieving the TBA values in every performance area is not only highly unlikely but also very likely to be uneconomical since there is a strong interaction between the various performance parameters; e.g. a plant could spend more to achieve increased availability but the cost could be excessively high. Therefore, instead of trying to maximize each of its performance parameters a plant's goals should be the *set* of indices that will *optimize* the plant's value to its company and its customers.

PGP APPROACH TO DATA COLLECTION

The Scope

For many years, WEC PGP Committee collected power plant availability statistics from the various countries as average indices for several groups of units. That may be help to a few people but not to the majority. PGP Committee members felt that there was a need to expand and improve the database for more thorough evaluations.

Starting in 1994, PGP opened the data collecting process to include unit-by-unit information. This brings the PGP database into a brand new dimension and .includes individual unit design and performance indices. The design section of the database provides a number of characteristics for filtering the collected data into various groups based on the requester's concepts of what constitutes a peer unit. The performance indices allowed distributions needed for benchmarking and goal setting activities. Average numbers were not sufficient; distributions answered the call for detailed analysis tools. Future improvements to the PGP database are needed to include analysis of failure modes and the root causes of unavailability.

The PGP database now allows all operating units to report to it. The design and operation filtering characteristics will allow the data requester to choose the operating parameters of units most similar to their own. The performance indices expand the options to peaking, cycling or base-loaded units too. This flexibility will allow more and more use of the database for comparing individual unit performance to peer units.

Definitions and Terminology

The calculation methodology and rules in the PGP database broadly reflect the existing standards and their use should be encouraged within the framework of the WEC survey. The documents uniformly used for definitions and calculations include:

- Eurelectric publication "TherPerf data base: Evaluation of Performance Indicators 1990-2004"
- IEEE Standard 762 "Definitions for Reporting Electric Generating Unit Reliability, Availability and Productivity"
- ISO Standard 3977 "Gas Turbine - Procurement – Part 1; Introduction and definitions." This standard was introduced in 1997 and contains many of the same definitions as IEEE 762.
- International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS) database.

- World Association of Nuclear Operators (WANO) database.

Both Eurelectric and IEEE 762 definitions are used worldwide by the majority of companies throughout Europe, Asia, Africa and North America. However in this publication we were referred to the Eurelectric definitions as a primary source but also refer to IEEE 762 as appropriate.

A number of Member countries reported their data so that four core (primary) performance indicators can be calculated. These four indicators have thus been defined, (See Appendix 2-1) for international application, for the different areas in which operators must ensure a high degree of vigilance in order to achieve a satisfactory quality of service:

Four Core (Primary) Performance Indicators

1. Energy Availability Factor (EAF)
2. Load Factor (LF)
3. Planned Capacity Loss Factor (PCLF)
4. Unplanned Capability Loss Factor (UCLF)

The PGP collects unit-by-unit performance hours/MWh lost so that the database will calculate the same core performance indices, even when they are not be calculated by the countries that supply them. As a result, the PGP database will allow data users to filter data based on the MW size of the unit, hours of operation, unplanned outage hours and many other parameters.

The focus of the PGP database is to create a higher-quality management tool. These core values are intended principally for use by operators to monitor their own performance and progress, to set their own challenging goals for improvement, and to gain an additional perspective on performance relative to that of other plants. It provides the tool for more detailed benchmarking of units by operation and design. It also provides the flexibility to allow the data requester to examine and compare units based on their own desired criteria and not on the fixed, rigid output of some cyclic, published reports.

PGP Database – Developer, Operator and User

The PGP database was developed

- By skilled people, who did a similar job on national or regional level before and had the experience for a worldwide solution

- For WEC, which is known as neutral platform for exchange of knowledge and which can help spread and improve well and best practice all over the world for everyone's benefit

- For technicians in power plants, who need orientation for their daily work.

PGP database can be accessed by anyone anytime from everywhere. It is always available via internet. Everyone can register and receive permission to enter the data pool, which may help to answer questions like:

- What availability could be demanded from and should be guaranteed by the supplier, when a new plant is ordered?

- What energy unavailability has to be taken into account, when a decision prefers one big unit – two half-sized units?

- How long will a revision last in an average year in a peer group?

- Do we have to encourage power plant staff to reduce repair time, because comparable plants show higher factors?

All these benefits can only be harvested when data collection in the plants and its evaluation are done in a uniform way by using fixed rules. These fixed rules are essential so that the results answer the questions asked about the plant situation.

It may be helpful to collect even more details than necessary for a comparison with the mentioned core performance indicators – for example more operational data like number of cold, warm, hot starts, number of operating cycles to part loads or causes of unplanned outages. This information can give useful indications for a root cause and a problem's solution.

WEC runs this database from the London Secretariat. Please direct all question, comments and concerns to
http://www.worldenergy.org/128.asp.

TWO EXAMPLE USES OF PGP DATABASE

To illustrate the power and use of the PGP database, we will choose two of the many applications: benchmarking and goal setting.

Benchmarking

One of the best methods for demonstrating the use of PGP data is benchmarking. What is meant by "benchmarking"?

The benchmarking process simultaneously considers the impact design and operational variables have on the reliability of an electric generating unit or group of similar units. The process uses the design characteristics and operational factors of the target unit groups as its starting point. The result is a statistically valid group of units having similar design and operational variables. *Within the peer unit grouping, the units are not the same, but they are not exactly different enough to be different*. Proper selection of design and operational variables is the key in defining an appropriate peer group. The benchmarking process provides a repeatable, statistically valid means of defining the peer group.

The PGP database has collected a number of key design and performance elements for benchmarking work. The elements came from utility engineers and workers surveys as to what characteristics are most important in peer group selections. Not all engineers or workers agreed all specific items so we collecting a list from you to choose from based on your own experience. The design elements are shown in Appendices 2-2-A to 2-2-D and the performance elements are in Appendix 2-2-E.

Suppose that you operate a base-loaded, natural circulation, fossil steam unit. The unit has a tandem-compound steam turbine with a reference capacity of 350 MW. The furnace is balanced-draft. Using the PGP database, you can search the database using the following criteria:

- Thermal steam turbine units
- Circulation type: controlled
- Steam turbine type: tandem compound
- Fuel: all fuels (coal, oil and natural gas)
- Draft: Balanced draft.
- MW size between 200 and 400 MW
- Study period: between the years 2004 and 2008 (five years)

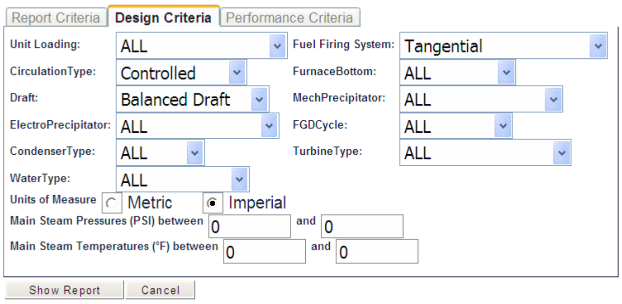


Figure 2-1 – Thermal steam turbine design options

In this study, we want base-loaded units. But base-loaded may mean different things to different people. In our example, we will assume that a base-loaded unit operates more than 4,000 hours per year with low number of unplanned outages hours. Thus, our operating (performance) criteria would be:

- Service hours: 4000 to 8000 hours annually
- Unplanned outage hours: 100 to 600 hours annually.

Report Criteria | Design Criteria | **Performance Criteria**

Service Hrs: between	4000	and	8000
Available Hrs: between	0	and	0
Planned Outage Hrs: between	0	and	0
Unplanned Outage Hrs: between	100	and	600
Reserve Hrs: between	0	and	0

Show Report | Cancel

Figure 2-2 - Thermal steam turbine performance options

PGP database site identifies 61 units that meet the criteria. The distribution of Energy Availability Factor (EAF) for the peer group is:

Quartiles & Deciles

Percentile	Value
Min	66.56
d1	77.90
d2	79.09
Q1	79.99
d3	81.05
d4	82.38
Q2	84.09
d6	85.08
d7	86.99
Q3	88.24
d8	88.46
d9	89.62
Max	96.04

Figure 2-3 – Quartile & Deciles Distributions of Peer Group
Energy Availability Factor (EAF)

EAF Distribution Summary

Range of EAF Values	Count	Cumulative Count	Cumulative Percent
0-9.99%	0	0	0%
10-19.99%	0	0	0%
20-29.99%	0	0	0%
30-39.99%	0	0	0%
40-49.99%	0	0	0%
50-59.99%	0	0	0%
60-69.99%	2	2	3.23%
70-79.99%	14	16	25.81%
80-89.99%	40	56	90.32%
90-100%	6	62	100%

Figure 2-4 – Energy Availability Factor (EAF) Distributions of Peer Group

In reviewing the results in Figure 2-4, we ask "which units had the EAF of 90-100% and from which countries?" This information is not available. All units in the PGP are blended together so no one country or contributing reporter can be identified in any PGP reports. *Confidentiality is very important. Your data will be confidential!.*

Now, you have some important results for benchmarking or establishing realistic goals for comparing your unit to others operating like your unit. Other graphs and other tables can be produced from the data for combustion turbines, combined cycles, co-generators, hydro/pumped storage and nuclear units.

To see more examples of this important and unique database, go to the PGP database website http://pgp.worldenergy.org:8244/.

Setting Realistic Unit Goals

Benchmarking your generating units is a key to setting achievable goals for these units. Once the benchmarking is complete, you can review the distributions and mark the goals.

Suppose that you want your unit to be in the top 75% EAF of its peer group. When you look at the distribution of Figure 2.3, we learn that the 3rd quartile is 88.24%. That means that the unit must achieve an EAF of 88.24% or greater to be above the 3rd quartile goal. Distributions of PCLF, UCLF, and other key performance indicators can work in harmony to set 1, 3, 5 or other year goals.

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 electric companies contribute to the database. How can you contribute to PGP?

HOW TO CONTRIBUTE TO THE PGP DATABASE

For a number of years, the WEC Member Committees collected and reported power plant data to PGP. Confidentiality is very important, so is keeping the data away from competitors. This limited the type and amount of data each generating company wanted to send to the PGP database. The rules are now available so that utilities can report their data directly to PGP without passing it through its member organizations or through three international databases. 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 electric companies from that region. This move is to maintain the confidentiality of the PGP data while allowing reporting of confidential data to PGP.

ll data is blended together and combined to allow grouped distributions and group statistical reports – keeping all data confidential.

There are four ways you can contribution your generating unit data to PGP.

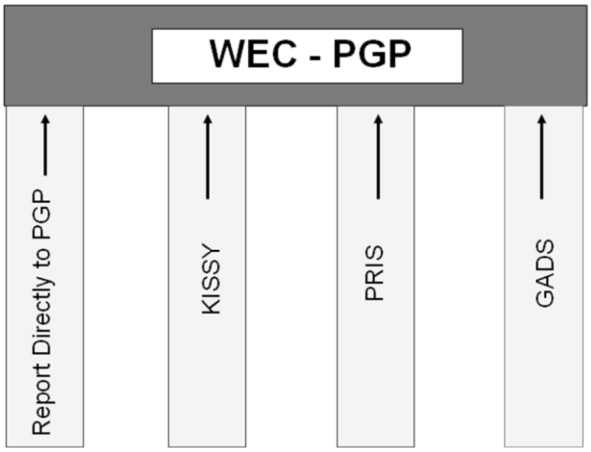


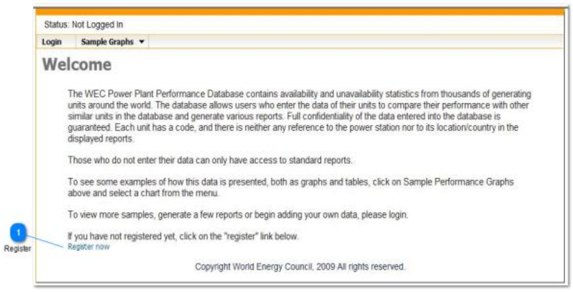
Figure 2-5 – Methods to Contribute to PGP Database

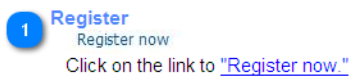
Report Directly to PGP

1. There are several steps to enter data into the PGP directly. Here is the WEC PGP database walk-thru:

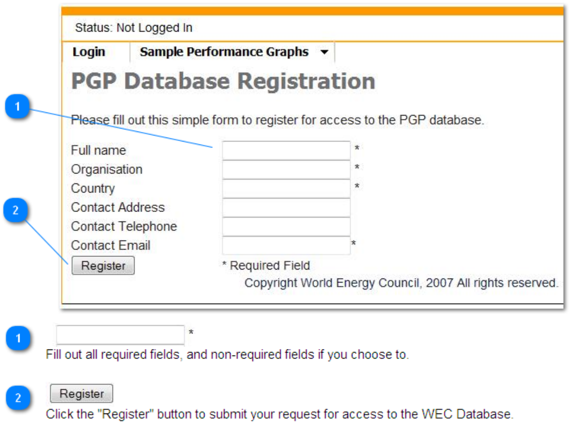
    a. **First, you register with PGP**:

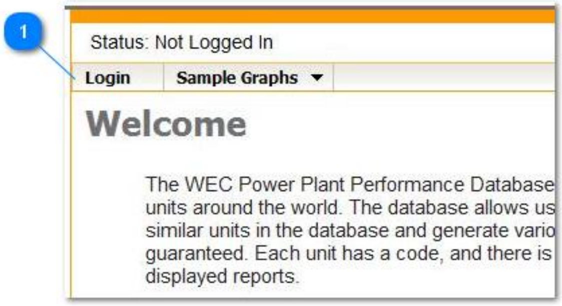
After coming to the Welcome screen and reading the introduction, you must register as a new user before being able to input new data. Click this link to see the next step: Registration Form



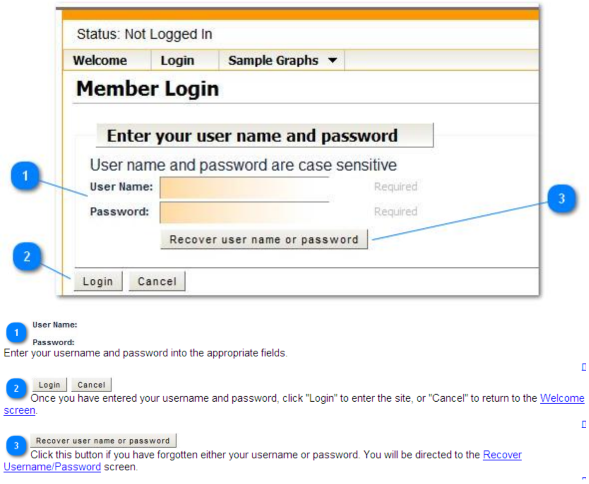


After clicking the "Register now" link, you will be able to fill out a request form for access to the WEC Database

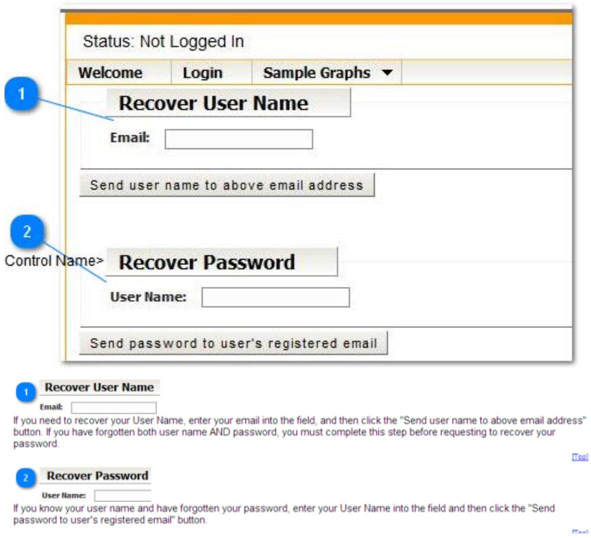




This is the log in screen. You may Log In from this screen, or Recover a lost username/password.

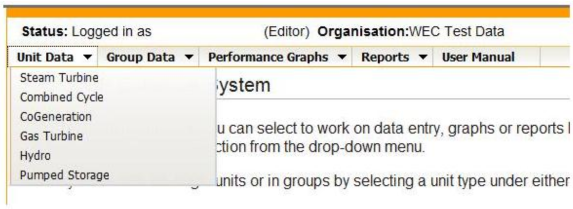


If you have, for some reason, forgotten either your user name or password (or both!), you may enter the information you DO know into the appropriate fields, and the lost information will be sent to the email address you registered with.

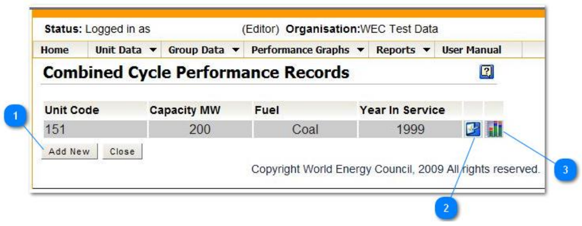


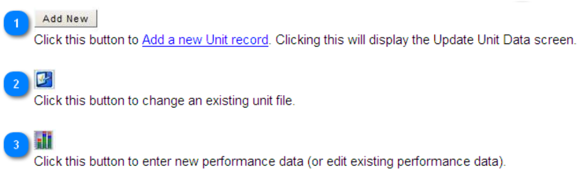
a. How to enter new data

Once you have registered and logged in, you may now enter a new unit and its accompanying data. From the main screen after you login, choose a Unit type from the Unit Data menu, as shown below.

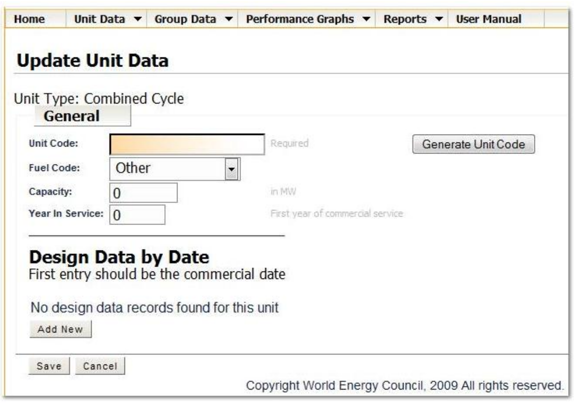


For this example, we have chosen to insert a new Combined Cycle unit.





This screen is displayed when you choose to add a new Unit.



Report Through the KISSY Database

The KISSY database is operated by VGB, which is an association for power plant operators. Four years ago, Eurelectric mandated VGB to integrate the European TherPerf-activities into KISSY to concentrate European data collection. Since 2003 VGB was already evaluating the data and created the Eurelectric-reports by order of Eurelectric.

At that time VGB started providing WEC with the core indicator data in a cycle of 3 years. In 2010 VGB is adapting the data supply of the PGP database to a yearly cycle, to an anonymous unit-by-unit delivery and – most important – is obtaining the permission of the data supplier, to support the PGP data supply out of the KISSY-database, which also means a relief of work for the companies.

For more information of KISSY, see Appendix 2-3-A.

Report Through the PRIS Database

The Power Reactor Information System (PRIS) is maintained by the International Atomic Energy Agency (IAEA). The monthly production and power losses data have been recorded in PRIS since 1970. The data and information are reported to the Agency through designated national correspondents. PRIS contains production data from all operating Nuclear Power Plants.

PRIS is used as a reference database for nuclear power plants and is ready to supply to the PGP database key indicators for all individual power reactor units respecting the established confidentiality rules.

For more information of PRIS, see Appendix 2-3-B.

Report Through the GADS Database
The Generating Availability Data System (GADS) is operated by North American Electric Reliability Corporation (NERC) in the United States. GADS has been collecting equipment outage information on North American generating units since 1982. In 2008, more than 5,800 generating units (782,000 MW) reported to GADS.

GADS contributed its data to the PGP database to boost the unit population and help PGP users. It has the necessary software to convert the GADS-formatted data into the form needed for PGP use. All units are encrypted before being added to PGP to maintain confidentiality.

To join GADS as an international member, the cost is US$1,000 annually. But with the membership, there is access to the full GADS database. For more information, contact gads@nerc.com.

For more information of GADS, see Appendix 2-3-C.

CONFIDENTIALITY OF DATA IS IMPORTANT

As mentioned earlier, confidentiality is extremely important to the WEC and its PGP database. We are taking pain-staking efforts to insure safety for your data.

- All data sent to PGP database is <u>confidential</u>!
- All data is encrypted <u>*by the reporting companies*</u> <u>before</u> entry into the PGP so that no one can identify another unit by name, description, key performance indicators (KPI), etc.
- No “real time” data is collected; only historical information.
- Data is not identified by countries. This option allows both large and small electric companies to report to PGP without allowing other companies with the countries to see your data. In other words, *your competitors will not have access to your data*!

If requested, WEC will sign a confidentiality agreement stating that your contribution to PGP will be save from access by other generating companies or other groups.

WHAT THE FUTURE HOLDS IN STORE

The benefits of the international cross-comparison system henceforth depend - in addition to the current practices described in this report - on the commitment of power plant operators to enhancing them. The underlying goal is to foster international support and participation.

Nevertheless, additional factors have to be taken into consideration. These factors refer to the different kinds of responsibilities for each type of energy losses: external versus internal (for example, environmental constraints as opposed to equipment reliability and human performance), and technical versus commercial. In addition, the introduction of the concept of commercial availability could help to better address technical performance of generating plants in the competitive electricity market.

With time, the PGP database will need expansion to investigate more detailed factors of unavailability. It may be helpful to collect in the plants even more details than necessary for a comparison with the mentioned core performance indicators – for example more operational data like number of cold, warm, hot starts, number of operating cycles to part loads or causes of unplanned outages. This information can give useful indications for a root cause and a problem’s solution.

The WEC PGP Committee will continue producing statistics that will offer value to all electricity producers worldwide and it has started work to widen the analysis aspects of the database. The PGP’s unit-by-unit database now includes data selections based on design and annual performance characteristics for use in benchmarking, reliability determinations, and evaluating new and old unit designs as well as other applications for increasing the productivity and reliability of plant equipment. The PGP database is still in its infant stage at this point but will grow and more and more countries report data to the PGP on unit-by-unit bases.

Conclusions

Key factors influencing plant performance should be identified and analysed 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 new 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 wonder exchange of information to better the quality of life for the world community.

APPENDIX 2-1

BRIEF DESCRIPTION OF THE CORE PERFORMANCE INDICATORS MONITORED BY THE WEC PGP COMMITTEE

Energy Availability Factor (EAF)

EAF is a percentage and measures of the potential amount of energy that could be produced by the unit after all planned and unplanned losses are removed. Not all the **available energy will be created. However,** EAF will identify what percentage of power during a period *could be* generated. Outside management control (OMC) problems are included in EAF. Energy Availability Factor is equal to IEEE 762 Weighted Equivalent Availability Factor (WEAF) which includes outside management control outages or derates.

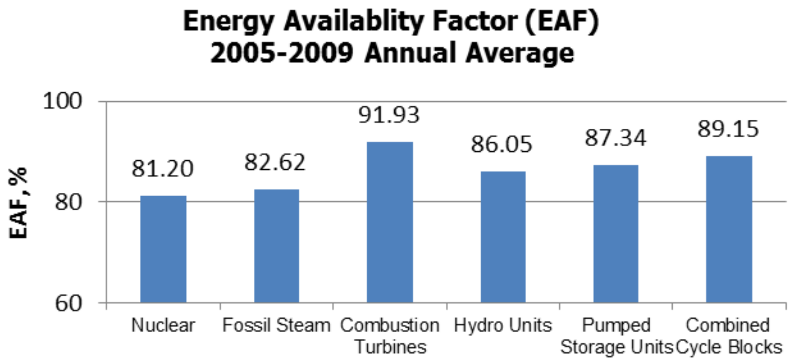


Figure 2-6 – Example of EAF Statistics
(Note: Nuclear is worldwide data; all others are North American data)

Load Factor (LF)

Load Factor is the percent of maximum energy the unit actually did produce. With regards to EAF, EAF presents what the unit could produce; LF presents what the unit actually did produce. LF is equal to IEEE 762 Net Capacity Factor (NCF).

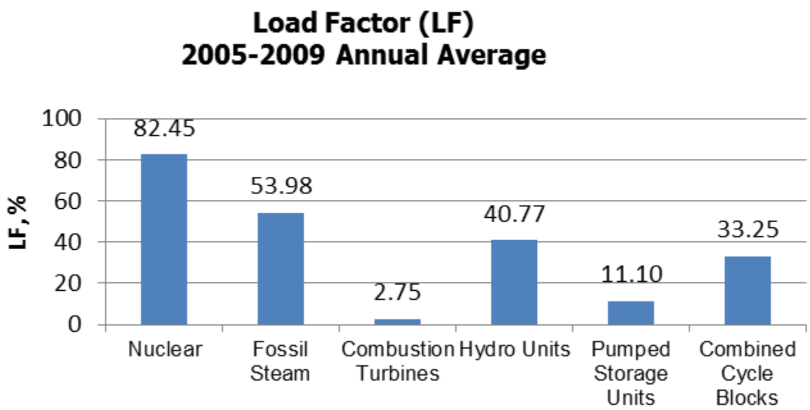


Figure 2-7 – Example of LF Statistics
(Note: Nuclear is worldwide data; all others are North American data)

Planned Capability Loss Factor (PCLF)

Planned Capability Loss Factor is the percentage of maximum energy generation that a plant is not capable of supplying to the electric grid because of planned energy losses (such as annual maintenance shutdowns). Energy losses are considered planned if they are scheduled at least four weeks in advance. PCLF is equal to IEEE 762 Weighted Equivalent Planned Outage Factor (WEPOF).

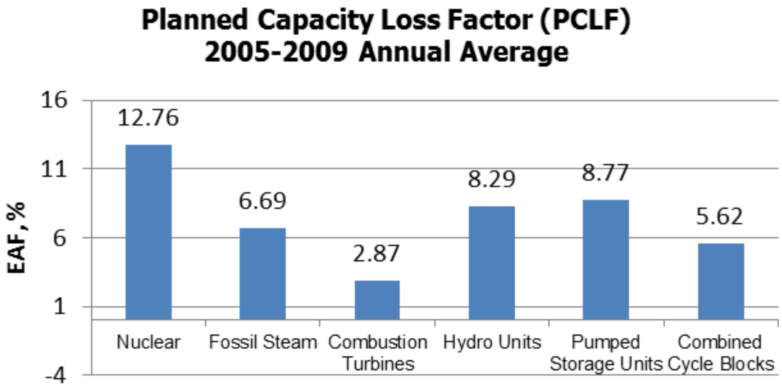


Figure 2-8 – Example of PCLF Statistics
(Note: Nuclear is worldwide data; all others are North American data)

Unplanned Capability Loss Factor (UCLF)

Unplanned capability loss factor is the percentage of maximum energy generation that a plant is not capable of supplying to the electrical grid because of unplanned energy losses (such as unplanned shutdowns, outage extensions or load reductions due to unavailability). Energy losses are considered unplanned if they are not scheduled at least four weeks in advance. A low value for this indicator indicates that important plant equipment is reliably operated and well maintained. UCLF is equal to IEEE 762 Weighted Equivalent Unplanned Outage Factor (WEUOF).

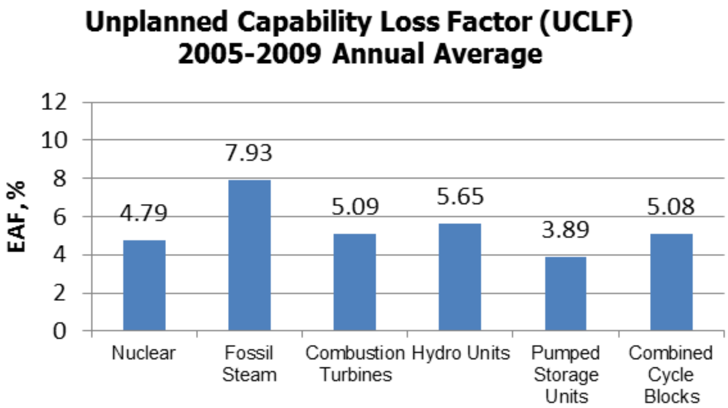


Figure 2-9 – Example of UCLF Statistics
(Note: Nuclear is worldwide data; all others are North American data)

Appendix 2-2-A
Brief Description of Thermal Steam Turbine Unit Design

- **Year and month the unit was first commercially operated**
- **Unit Loading Characteristics at Time of Design** (six options including 1-base load with minor load following; 2-periodic start-up, load follow daily, reduced load nightly; 3-weekly start-up, load follow daily, reduced load nightly; etc)
- **Boiler - Fuel Firing System** (nine options including *Front OR Back* - wall mounted burners on either the front OR the back of the furnace; *Opposed* - wall mounted burners on BOTH the front and back of the furnace; *Tangential* - firing from the corners of the furnace with burners capable of directing the fireball up or down; etc.)
- **Boiler - Type of Circulation** (three options including 1-*Natural* (thermal) - water flows through furnace wall tubes unaided by circulating pumps. Primarily used with subcritical units; 2-*Controlled* (forced or pump assisted thermal) - water flows through furnace wall tubes aided by boiler recirculation pumps located in the downcomers or lower headers of the boiler. Used on some subcritical units; etc.)
- **Boiler - Type of Furnace Bottom** (two options including 1-*Dry bottom* - no slag tanks at furnace throat area (throat area is clear). Bottom ash drops through throat to bottom ash water hoppers. Design used when ash melting temperature is greater than temperature on furnace wall, allowing for relatively dry furnace wall conditions; 2-*Wet Bottom* - slag tanks installed at furnace throat to contain and remove molten ash from the furnace.
- **Type of fuel**
- **Boiler - Balanced Draft or Pressurized Draft**
- **Boiler - Mechanical Fly Ash Precipitator System**
- **Boiler - Electrostatic Precipitator**
- **Flue Gas Desulphurization Data** listing unit of FGD installation and type of FGD cycle.
- **MW nameplate rating.**
- **Steam Turbine - Type of Steam Turbine** (four options including 1-*Single casing* - single (simple) turbine having one pressure casing (cylinder); 2 -*Tandem compound* - two or more casings coupled together in line; 3-*Cross compound* - two cross-connected single casing or tandem compound turbine sets where the shafts are not in line.
- **Steam Turbine - Steam Conditions** for information on the Main, First Reheat, and Second Reheat Steam design conditions.
- **Auxiliary Systems - Main Condenser** describing the type of water (fresh, salty) and source of water (river, lake, cooling tower) for cooling the condenser.
- **NO_X Reduction Systems** includes Selective Non-catalytic Reduction, Selective Catalytic Reduction, Catalytic Air Heaters, and Staged NO_X Reduction, which is a combination of the three methods.

Appendix 2-2-B
Brief Description of Combined Cycle/Co-Generator Unit Design

- **Year and month the unit was first commercially operated**
- **Unit Loading Characteristics at Time of Design** (six options including 1-base load with minor load following; 2-periodic start-up, load follow daily, reduced load nightly; 3-weekly start-up, load follow daily, reduced load nightly; etc)
- **Total Nameplate Rating of all units in the block (in MW)**
- **Does the block have co-generation** (steam for other than electric generation)
- **What is the number of gas turbines/jet engines per Heat Recovery Steam Generator (HRSG)?**
- **What is the number of gas turbines/jet engines - Heat Recovery Steam Generator (HRSG) Train?**
- **Total number of gas turbines/jet engines in block.**
- **Total number of Heat Recovery Steam Generator (HRSG) in block.**
- **Total number of Steam Turbines in block.**
- **Type of fuel**

Appendix 2-2-C
Brief Description of Combustion Turbines Unit Design

- **Year and month the unit was first commercially operated**
- **Unit Loading Characteristics at Time of Design** (six options including 1-base load with minor load following; 2-periodic start-up, load follow daily, reduced load nightly; 3-weekly start-up, load follow daily, reduced load nightly; etc)
- **Engine type** - (three options including gas turbine single shaft; gas turbine split shaft; Jet engine (or aero derivative)
- **Type of fuel**
- **MW nameplate rating**

Appendix 2-2-D
Brief Description of Hydro or Pumped Storage Unit Design

- **Year and month the unit was first commercially operated**
- **Unit Loading Characteristics at Time of Design** (six options including 1-base load with minor load following; 2-periodic start-up, load follow daily, reduced load nightly; 3-weekly start-up, load follow daily, reduced load nightly; etc)
- **MW nameplate rating**
- **Type of unit** (three options including 1- Hydro; 2- Pump/turbine; 3- Pump)
- **Turbine/Pump reaction type** (four options including 1- *Francis*; 2-*Kaplan* – adjustable blade propeller; 3- *Fix blade propeller*; 4-Pump/turbine;
- **Turbine rated head to nearest foot**

Appendix 2-2-E
Description of Performance Data
For All Unit Types

- **Unit Service Mode (or Unit Operating Mode)**
The number of hours the unit was synchronized to the system (breakers closed, providing power to the grid). For units equipped with multiple generators, count only those hours when at least one of the generators was synchronized, whether or not one or more generators were actually in service.

- **Available Mode**
For those collecting data in hours – The sum of the Unit Service Hours, Reserve Shutdown Hours, Pumping Hours (if applicable), and Synchronous Condensing Hours (if applicable).

  For those collecting data on an energy basis – The sum of the Unit Service, Reserve Shutdown, Pumping (if applicable), and Synchronous Condensing (if applicable) MWh for the unit. This is calculated by multiplying the number of hours the unit was in the service, RS, pumping and synchronous condensing mode times the reference capacity.

- **Planned Outage Loses**
The total energy loss due to planned outages.
To IEEE 762 reporters, this would be the MWh lost due to planned outages and planned derates. This is calculated by multiplying Planned Outage Hours and the Equivalent Planned Derated Hours by the reference capacity.

- **Unplanned Outage Losses**
The total energy losses due to unplanned outages. This does not include those losses attributed to causes that are out of management control.
To IEEE 762 reporters, this would be the MWh lost due to Forced and Maintenance outages and derates (U1, U2, U3, SF, MO, D1, D2, D3 and D4 events). This is calculated by multiplying the summed outage hours and the equivalent derated hours by the reference capacity.

- **Reserve Shutdown Mode (or Economic Mode)**
For those collecting data in hours – The sum of all hours the unit was available to the system but not synchronized for economy reasons. During the RS time, the unit is capable of generating but is not because it is not needed for load or management decides not to operate it.

  For those collecting data on an energy basis – The sum of MW hours the unit could have produced at full load if the unit was in operation but is not synchronized for economy reasons. During RS, the unit is capable of generating but is not because it is not needed for load or management decides not to operate it. This is calculated by multiplying the number of hours the unit was in economic shutdown mode times the reference capacity.

  If not reported, this value is calculated as the difference between Available Energy and Actual Generation.

APPENDIX 2-3-A

INTERNATIONAL DATABASES SUPPORTING THE WEC PERFORANCE OF GENERATING PLANT (PGP) DATABASE

KraftwerkInformationSSYstem (KISSY)

The KISSY database is operated by VGB of Essen Germany. It is an association for power plant operators and currently has a membership of 12 different European countries. Therefore KISSY offers its online surface in 6 different languages, which can be chosen by a click on a flag at the top of their home page.

Data are collected on the base of rules and standards, methods and formula of a guideline, which has been developed by a panel of VGB members over 4 decades. The database KISSY contains data of thermal power plant units. Some master data like design data are necessary for calculations of indicators or data selections. All data provider take part at the availability module, which means, they fill in datasets of about 30 different entries per unit – in case of nuclear plants monthly and all others yearly. The unavailability module requires event data of incidents with the consequence of a planned, unplanned unavailability or an external influence.

Data can be entered into KISSY by internet, bulk import, csv-file or sending paper reports to VGB. Direct data input into KISSY by the provider is much faster and easier to avoid long processing times.

Only VGB-KISSY administrators are able to see the original, non-anonymous data. All other users are able to evaluate and see results of selected classes of anonymous plants. The technical-scientific (standard) reports will inform not only the data suppliers, but are also available for the public. Additionally the results are discussed in workshops, in the working panel and in thematically publications.

APPENDIX 2-3-B

INTERNATIONAL DATABASES SUPPORTING THE WEC PERFORANCE OF GENERATING PLANT (PGP) DATABASE

Power Reactor Information System (PRIS)

PRIS is a comprehensive data source on nuclear power reactors in the world. It includes specification and performance history data of operating reactors as well as reactors under construction or reactors being decommissioned.

The reactor specification data consist of basic information (location, operator, owner, suppliers, milestone dates) and design technical characteristics. The performance data includes energy production and loss data as well as outage and operational event information.

The monthly production and power losses data have been recorded in PRIS since 1970. Recently the electricity production data were complemented also by information on energy provided by nuclear power plants to non-electrical applications like district heating, process heat supply or desalination. Information about decommissioning process of shutdown units has been also incorporated in PRIS.

Due to detailed classification of energy losses and 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. These analyzes can be suitably utilized in evaluation of nuclear power competitive advantages compared with other power sources.

PRIS outputs are available in annual publications, on the public PRIS Web Site, and to registered users through on-line applications.

The “Nuclear Power Reactors in the World”, which is published since 1981, is one of the most popular annual publication of IAEA. The publication “Operating Experience with Nuclear Power Stations in Member States” is published since 1971 and consists of comprehensive information about operational experience of each individual reactor unit.
Registered users have on-line access to PRIS through WEB based applications supporting data collection and performance indicator reporting.

The PRIS website http://www.iaea.org/pris provides information for public. It is one of the most frequently IAEA gateways.

APPENDIX 2-3-C

INTERNATIONAL DATABASES SUPPORTING THE WEC PERFORANCE OF GENERATING PLANT (PGP) DATABASE

Generating Availability Data System (GADS)

GADS Services manages the Generating Availability Data System (GADS) for the North American Electric Reliability Corporation (NERC).

Since 1968, the NERC has been committed to ensuring the reliability of the bulk power system in North America.

To achieve that, NERC develops and enforces reliability standards; assesses adequacy annually via a 10-year forecast and winter and summer forecasts; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is a self-regulatory organization, subject to oversight by the U.S. Federal Energy Regulatory Commission and governmental authorities in Canada.

GADS is a unique series of databases to collect, record, and retrieve operating information for improving the performance of electric generating equipment. It also provides assistance to those researching the vast amounts of information on power plant availability stored in its database. The information is used to support equipment reliability and availability analyses and decision-making by GADS data users.

GADS Services supports the World Energy Council (WEC) in its analysis of electric power supplies. GADS staff participates in WEC committees and teaches workshops in developing countries. The WEC Performance of Generating Plant (PGP) Committee is developing a GADS-type program for collecting power plant outage data worldwide. GADS has worked with PGP members over the past years to provide WEC with GADS-type procedures for the uniform collection and reporting of plant outage data.

For more information on GADS, please visit our website at http://www.nerc.com/page.php?cid=4|43. For examples of GADS generating unit statistical reports, please go to http://www.nerc.com/page.php?cid=4|43|47.

All other inquires can be directed to gads@nerc.com.

APPENDIX 2-4

CORE PERFORMANCE INDICATOR FOR ALL UNITS REPORTING UNIT-BY-UNIT DATA, ALL COUNTRIES, BY UNIT CLASS AND FUELS

Nuclear Units
Figure 2-4-A

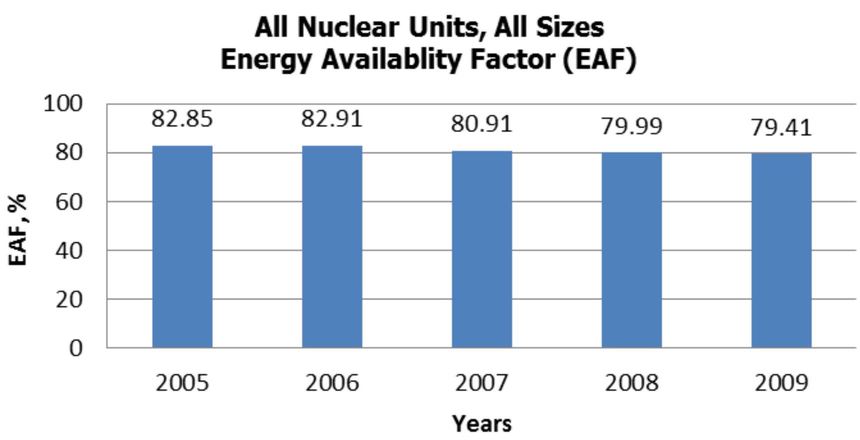


Table 2-4-A-1
Nuclear Unit Energy Availability Factor (EAF)
Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	441	82.85	442	82.91	439	80.91	439	79.99	438	79.41
BWR	93	80.35	93	82.04	94	76.03	94	74.14	94	72.99
FBR	2	76.53	2	73.39	2	72.26	2	73.72	2	65.58
GCR	22	71.54	22	65.06	18	58.77	18	49.64	18	68.65
LWGR	16	75.02	16	69.49	16	74.93	16	75.77	16	80.60
PHWR	41	81.48	42	81.85	44	78.02	44	76.50	44	75.49
PWR	267	84.71	267	84.75	265	84.02	265	83.68	264	82.35

Where
BWR = Boiling Water Reactor
FBR = Fast Breeder Reactor
GCR = Gas-Cooled Reactor
LWGR = Light-Water-Cooled, Graphite-Moderated Reactor
PHWR = Pressurized Heavy-Water Reactor
PWR = Pressurized Water Reactor

Table 2-4-A-2
Nuclear Unit Load Factor (LF), Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	441	82.12	442	82.05	439	80.41	439	79.53	438	78.70
BWR	93	80.16	93	81.71	94	75.45	94	73.90	94	72.70
FBR	2	76.22	2	73.39	2	72.19	2	73.35	2	65.89
GCR	22	71.34	22	64.86	18	58.54	18	49.54	18	68.66
LWGR	16	74.69	16	70.06	16	75.73	16	75.62	16	79.79
PHWR	41	81.13	42	81.35	44	77.43	44	75.81	44	74.22
PWR	267	83.73	267	83.58	265	83.49	265	83.14	264	81.53

Table 2-4-A-3
Nuclear Unit Planned Capability Loss Factor (PCLF), Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF
TOTAL	441	12.06	442	11.84	439	12.38	439	13.87	438	13.61
BWR	93	13.51	93	11.71	94	14.30	94	20.43	94	18.46
FBR	2	19.64	2	21.65	2	22.91	2	21.72	2	33.95
GCR	22	14.90	22	15.77	18	15.06	18	16.30	18	13.86
LWGR	16	20.87	16	26.30	16	19.54	16	21.74	16	15.06
PHWR	41	11.80	42	8.91	44	10.72	44	11.71	44	15.21
PWR	267	11.02	267	11.26	265	11.39	265	11.30	264	11.66

Table 2-4-A-4
Nuclear Unit Unplanned Capability Loss Factor (UCLF), Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF
TOTAL	441	3.91	442	4.25	439	5.05	439	5.29	438	5.45
BWR	93	5.06	93	5.90	94	6.39	94	5.11	94	7.70
FBR	2	2.90	2	4.44	2	4.60	2	4.21	2	0.38
GCR	22	13.42	22	18.58	18	25.99	18	33.97	18	17.19
LWGR	16	0.83	16	3.16	16	2.97	16	2.06	16	4.18
PHWR	41	4.64	42	5.91	44	7.01	44	6.35	44	4.56
PWR	267	3.17	267	2.96	265	3.71	265	4.36	264	4.41

Fossil Steam Units
Figure 2-4-B

Fossil Steam Units, All Fuels, All Sizes

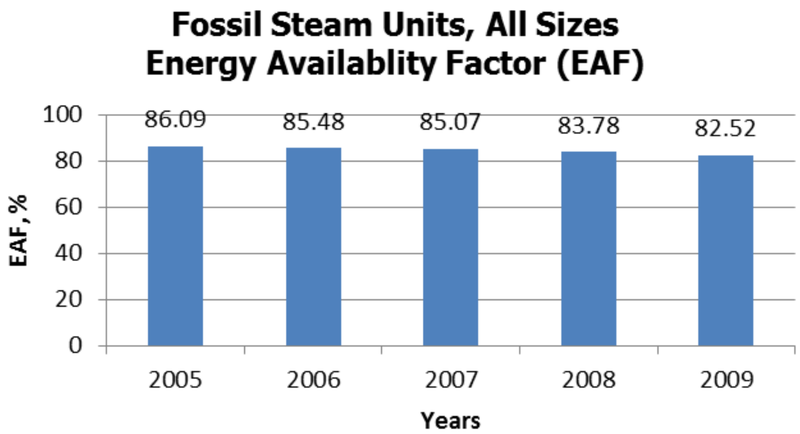


Table 2-4-B-1
Fossil Steam Unit Energy Availability Factor (EAF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**
TOTAL	1464	86.09	1409	85.48	1360	85.07	1389	83.78	1392	82.52
Coal	917	85.84	870	85.66	868	84.07	879	83.89	887	83.32
Liquid F	130	82.90	130	86.73	129	84.59	134	80.72	132	83.78
Gas	332	88.27	330	84.65	315	88.43	327	84.51	324	79.40

Table 2-4-B-2
Fossil Steam Unit Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**
TOTAL	1464	57.47	1409	55.59	1360	55.38	1389	52.90	1392	48.06
Coal	917	69.22	870	68.40	868	69.73	879	66.14	887	59.88
Liquid	130	27.72	130	17.69	129	18.03	134	14.58	132	11.30
Gas	332	14.78	330	13.79	315	13.38	327	13.31	324	12.46

Table 2-4-B-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	1464	6.55	1409	6.53	1360	7.07	1389	6.70	1392	6.61
Coal	917	6.27	870	6.36	868	6.75	879	6.73	887	6.49
Liquid	130	9.13	130	7.26	129	8.66	134	8.85	132	8.37
Gas	332	6.30	330	6.50	315	7.06	327	5.90	324	6.22

Table 2-4-B-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	1464	7.35	1409	7.28	1360	7.85	1389	8.48	1392	8.74
Coal	917	7.87	870	7.98	868	9.18	879	9.38	887	9.84
Liquid	130	7.98	130	5.23	129	6.75	134	8.16	132	7.08
Gas	332	5.42	330	6.06	315	4.51	327	6.09	324	6.37

Fossil Steam Units
Figure 2-4-C

Fossil Steam Units, All Fuels, 100-199 MW Sizes

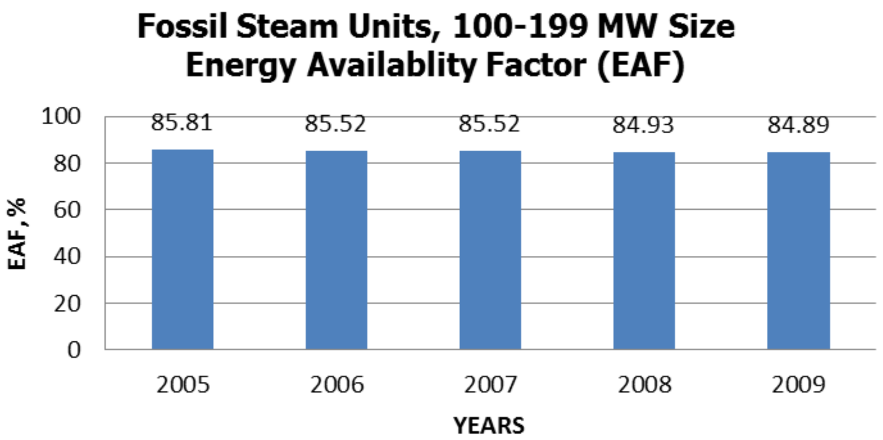


Table 2-4-C-1
Fossil Steam Unit Energy Availability Factor (EAF)
100-199 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	381	85.81	377	85.52	352	85.52	356	84.93	351	84.89
Coal	241	85.96	240	86.37	235	84.78	231	85.95	231	86.27
Liquid	37	82.24	36	85.85	33	83.42	36	79.12	35	85.13
Gas	91	87.99	91	82.70	82	89.10	86	84.75	82	81.44

Table 2-4-C-2
Fossil Steam Unit Load Factor (LF)
100-199 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	381	48.82	377	48.30	352	48.49	356	45.60	351	32.19
Coal	241	63.07	240	62.29	235	64.05	231	60.66	231	41.58
Liquid	37	31.36	36	27.74	33	29.87	36	26.84	35	19.96
Gas	91	12.61	91	11.52	82	10.34	86	9.31	82	8.39

Table 2-4-C-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
100-199 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	381	6.43	377	5.31	352	6.60	356	6.00	351	6.25
Coal	241	5.38	240	5.10	235	6.05	231	5.41	231	5.53
Liquid	37	10.56	36	7.18	33	9.33	36	8.63	35	8.58
Gas	91	7.56	91	5.39	82	6.81	86	6.23	82	6.78

Table 2-4-C-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
100-199 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	381	7.76	377	8.37	352	7.89	356	756.00	351	7.69
Coal	241	8.66	240	8.53	235	9.17	231	8.64	231	8.21
Liquid	37	7.20	36	6.97	33	7.25	36	6.69	35	6.29
Gas	91	4.45	91	8.48	82	4.10	86	5.42	82	6.77

Fossil Steam Units
Figure 2-4-D

Fossil Steam Units, All Fuels, 200-299 MW Sizes

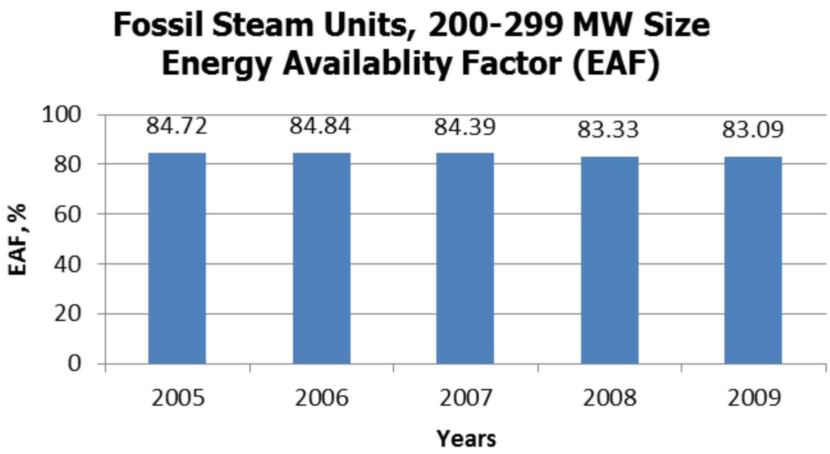


Table 2-4-D-1
Fossil Steam Unit Energy Availability Factor (EAF)
200-299 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	175	84.72	178	84.84	165	84.39	163	83.33	162	83.09
Coal	117	86.32	114	84.15	109	84.29	108	82.68	109	81.84
Liquid	13	76.23	12	83.73	12	80.42	11	76.58	11	79.34
Gas	41	82.34	42	87.83	39	86.15	39	86.96	39	87.28

Table 2-4-D-2
Fossil Steam Unit Load Factor (LF)
200-299 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	175	54.82	178	54.12	165	54.70	163	50.44	162	41.83
Coal	117	67.11	114	65.79	109	68.74	108	63.89	109	53.44
Liquid	13	30.95	12	31.63	12	31.62	11	24.36	11	16.68
Gas	41	23.38	42	20.95	39	18.77	39	17.91	39	15.15

Table 2-4-D-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
200-299 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	175	7.42	178	7.03	165	7.18	163	7.35	162	8.06
Coal	117	6.29	114	6.80	109	6.11	108	6.97	109	7.30
Liquid	13	10.49	12	9.85	12	11.62	11	15.92	11	16.65
Gas	41	10.17	42	6.32	39	8.22	39	6.18	39	7.85

Table 2-4-D-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
200-299 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	175	7.86	178	8.13	165	8.43	163	9.32	162	8.85
Coal	117	7.39	114	9.06	109	9.60	108	10.36	109	10.86
Liquid	13	13.27	12	6.43	12	7.95	11	7.51	11	4.01
Gas	41	7.49	42	5.85	39	5.63	39	6.86	39	4.87

Fossil Steam Units
Figure 2-4-E

Fossil Steam Units, All Fuels, 300-399 MW Sizes

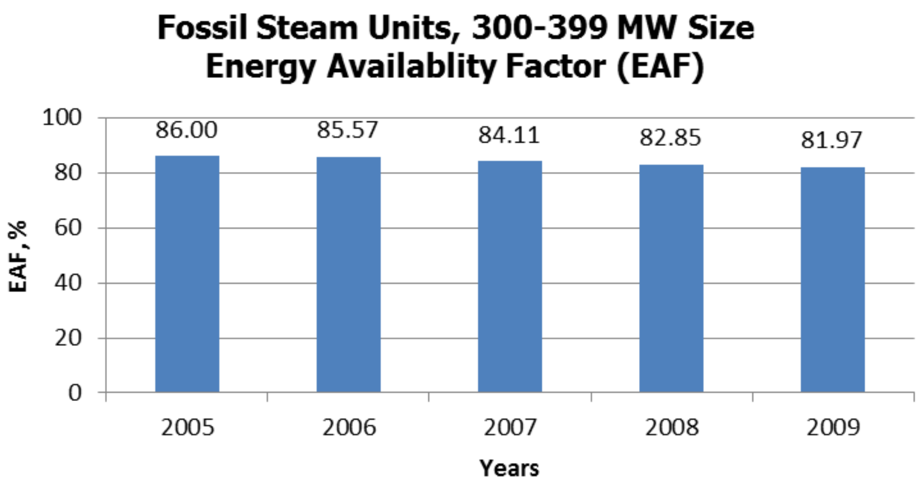


Table 2-4-E-1
Fossil Steam Unit Energy Availability Factor (EAF)
300-399 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	133	86.00	119	85.57	110	84.11	118	82.85	117	81.97
Coal	81	85.37	73	84.78	65	83.39	68	84.18	65	83.60
Liquid	7	77.35	7	82.74	9	79.45	11	76.59	11	79.55
Gas	34	89.18	36	87.74	36	86.58	39	82.25	39	80.42

Table 2-4-E-2
Fossil Steam Unit Load Factor (LF)
300-399 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	133	54.00	119	48.48	110	46.30	118	44.46	117	40.31
Coal	81	67.74	73	66.52	65	68.10	68	65.73	65	59.44
Liquid	7	50.04	7	32.23	9	24.64	11	15.89	11	12.94
Gas	34	13.58	36	12.44	36	12.75	39	13.51	39	12.74

Table 2-4-E-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
300-399 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	133	6.77	119	8.04	110	7.74	118	8.21	117	9.30
Coal	81	6.90	73	7.39	65	6.25	68	7.19	65	8.98
Liquid	7	16.72	7	14.05	9	15.34	11	14.65	11	15.78
Gas	34	5.44	36	8.50	36	8.53	39	8.19	39	7.41

Table 2-4-E-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
300-399 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	133	7.22	119	6.39	110	8.15	118	7.22	117	6.13
Coal	81	7.73	73	7.84	65	10.36	68	8.63	65	7.41
Liquid	7	5.93	7	3.21	9	5.21	11	8.76	11	4.67
Gas	34	5.38	36	3.75	36	4.90	39	4.22	39	4.19

Fossil Steam Units
Figure 2-4-F

Fossil Steam Units, All Fuels, 400-599 MW Sizes

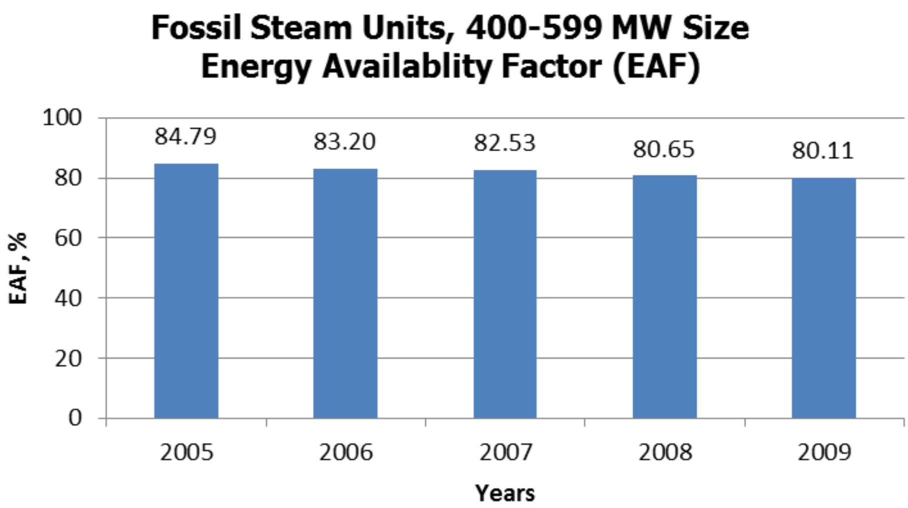


Table 2-4-F-1
Fossil Steam Unit Energy Availability Factor (EAF)
400-599 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**
TOTAL	226	84.79	211	83.20	205	82.53	206	80.65	220	80.11
Coal	145	83.80	122	85.38	131	81.04	132	82.48	144	80.88
Liquid	18	86.51	18	87.66	20	84.07	18	82.57	18	85.33
Gas	51	86.78	53	77.06	48	85.97	49	74.01	52	74.88

Table 2-4-F-2
Fossil Steam Unit Load Factor (LF)
400-599 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	226	55.07	211	53.49	205	50.62	206	50.03	220	46.38
Coal	145	69.88	122	71.18	131	68.37	132	65.20	144	59.64
Liquid	18	25.05	18	10.79	20	11.81	18	8.46	18	5.65
Gas	51	15.64	53	14.38	48	14.51	49	14.70	52	14.69

Table 2-4-F-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
400-599 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF
TOTAL	226	7.68	211	7.57	205	9.42	206	7.90	220	7.75
Coal	145	7.90	122	6.80	131	9.26	132	7.53	144	7.92
Liquid	18	7.43	18	8.57	20	11.59	18	12.93	18	8.12
Gas	51	6.98	53	8.89	48	9.14	49	7.39	52	7.32

Table 2-4-F-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
400-599 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF
TOTAL	226	7.47	211	7.33	205	8.04	206	9.48	220	9.83
Coal	145	8.22	122	7.82	131	9.70	132	10.00	144	11.20
Liquid	18	6.05	18	3.77	20	4.35	18	4.49	18	6.55
Gas	51	6.25	53	6.50	48	4.89	49	10.21	52	7.62

Fossil Steam Units
Figure 2-4-G

Fossil Steam Units, All Fuels, 600-799 MW Sizes

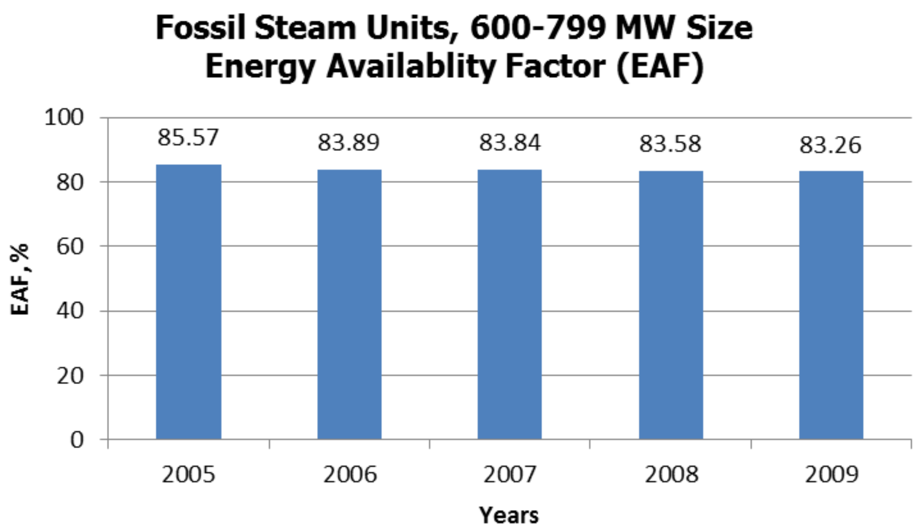


Table 2-4-G-1
Fossil Steam Unit Energy Availability Factor (EAF)
600-799 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	158	85.57	143	83.89	140	83.84	142	83.58	141	83.26
Coal	127	86.35	119	84.85	116	84.00	117	84.92	114	84.71
Liquid	7	74.80	7	90.58	7	78.04	7	69.48	9	70.59
Gas	12	85.22	10	65.74	10	84.51	11	75.75	11	79.40

Table 2-4-G-2
Fossil Steam Unit Load Factor (LF)
600-799 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	158	65.50	143	64.82	140	65.65	142	62.44	141	60.50
Coal	127	72.23	119	70.85	116	72.93	117	68.76	114	68.19
Liquid	7	28.70	7	16.38	7	17.68	7	15.17	9	14.08
Gas	12	9.37	10	11.38	10	11.43	11	11.94	11	11.68

Table 2-4-G-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
600-799 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	158	7.16	143	7.64	140	8.39	142	7.53	141	6.78
Coal	127	6.65	119	7.71	116	8.14	117	7.35	114	6.59
Liquid	7	15.37	7	5.12	7	10.61	7	10.20	9	8.61
Gas	12	8.53	10	9.01	10	10.56	11	10.06	11	7.31

Table 2-4-G-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
600-799 MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	158	7.21	143	7.06	140	7.78	142	8.18	141	9.25
Coal	127	6.92	119	7.44	116	7.86	117	7.72	114	8.70
Liquid	7	9.83	7	4.30	7	11.35	7	20.32	9	20.80
Gas	12	6.25	10	5.24	10	4.93	11	4.43	11	4.21

Fossil Steam Units
Figure 2-4-H

Fossil Steam Units, All Fuels, 800 MW and Larger Sizes

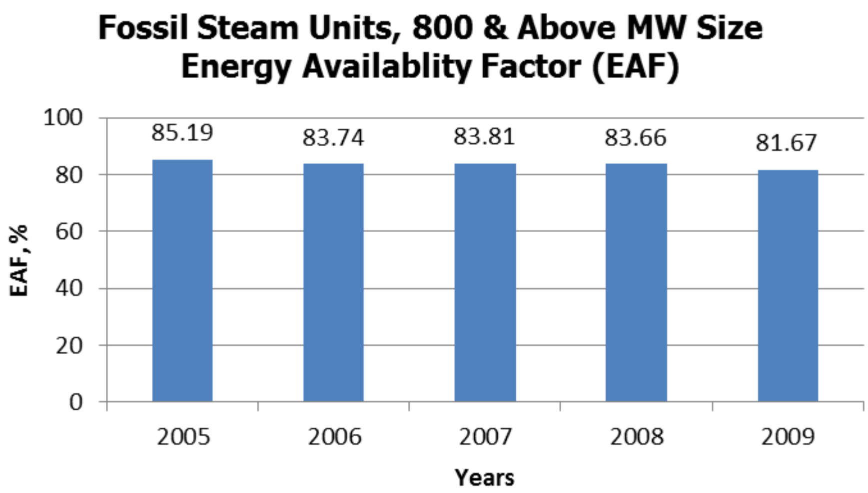


Table 2-4-H-1
Fossil Steam Unit Energy Availability Factor (EAF)
800MW and Larger Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	80	85.19	82	83.74	73	83.81	75	83.66	69	81.67
Coal	53	84.84	54	82.58	52	83.91	53	82.43	50	80.79
Liquid	11	83.28	11	89.51	11	85.72	11	85.91	9	81.46
Gas	5	83.94	6	72.83	4	67.83	5	85.03	4	83.72

Table 2-4-H-2
Fossil Steam Unit Load Factor (LF)
800MW and Larger Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	80	64.79	82	61.77	73	63.47	75	61.30	69	59.07
Coal	53	73.28	54	71.78	52	74.63	53	73.04	50	69.25
Liquid	11	20.67	11	9.86	11	11.21	11	8.42	9	4.97
Gas	5	17.84	6	13.82	4	15.25	5	14.42	4	10.95

Table 2-4-H-3
Fossil Steam Unit Planned Capability Loss Factor (PCLF)
800MW and Larger Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF
TOTAL	80	8.46	82	9.99	73	7.68	75	9.56	69	7.50
Coal	53	8.05	54	10.97	52	8.56	53	10.75	50	7.16
Liquid	11	10.16	11	7.01	11	5.48	11	5.37	9	9.30
Gas	5	12.86	6	13.81	4	8.41	5	10.94	4	13.05

Table 2-4-H-4
Fossil Steam Unit Unplanned Capability Loss Factor (UCLF)
800MW and Larger Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF
TOTAL	80	6.35	82	6.27	73	8.51	75	6.78	69	7.92
Coal	53	7.11	54	6.44	52	7.52	53	6.82	50	8.05
Liquid	11	6.57	11	3.48	11	8.80	11	8.71	9	9.23
Gas	5	3.20	6	13.36	4	23.76	5	4.04	4	3.24

Combustion Turbines
Figure 2-4-I

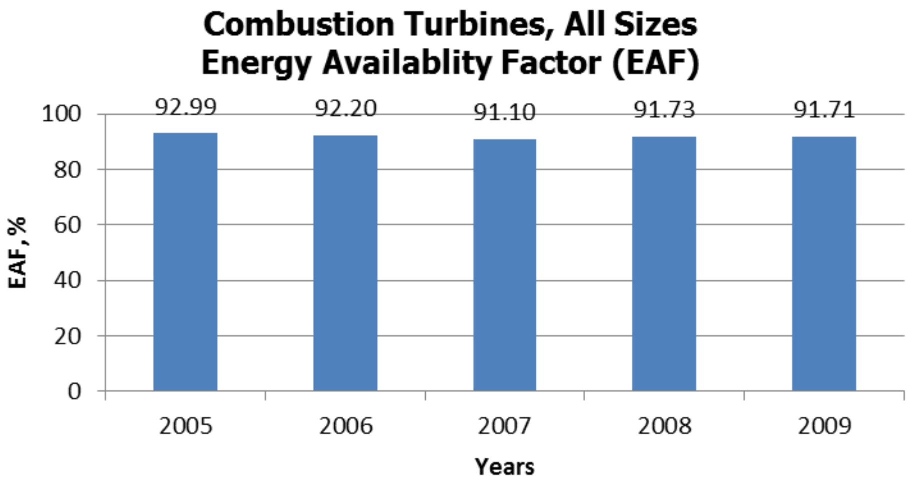


Table 2-4-I-1
Combustion Turbines Energy Availability Factor (EAF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	1460	92.99	1444	92.20	1462	91.10	1628	91.73	1663	91.71
Liquid	682	92.89	683	92.22	666	90.33	691	91.07	690	91.54
Gas	778	93.07	761	92.18	796	91.76	937	92.23	972	91.82

Table 2-4-I-2
Combustion Turbines Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	1460	3.31	1444	2.68	1462	3.57	1628	2.38	1663	1.99
Liquid	682	2.81	683	2.09	666	2.77	691	2.10	690	1.67
Gas	778	3.61	761	3.04	796	4.01	937	2.50	972	2.12

Table 2-4-I-3
Combustion Turbines Planned Capability Loss Factor (PCLF) All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	1460	2.32	1444	2.52	1462	3.29	1628	2.97	1663	3.20
Liquid	682	2.10	683	1.81	666	2.75	691	2.70	690	3.00
Gas	778	2.52	761	3.15	796	3.74	937	3.17	972	3.35

Table 2-4-I-4
Combustion Turbines Unplanned Capability Loss Factor (UCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**
TOTAL	1460	4.69	1444	5.21	1462	5.62	1628	5.18	1663	4.79
Liquid	682	5.01	683	5.82	666	6.93	691	6.08	690	5.02
Gas	778	4.41	761	4.66	796	4.50	937	4.50	972	4.62

Hydro Units - Figure 2-4-J

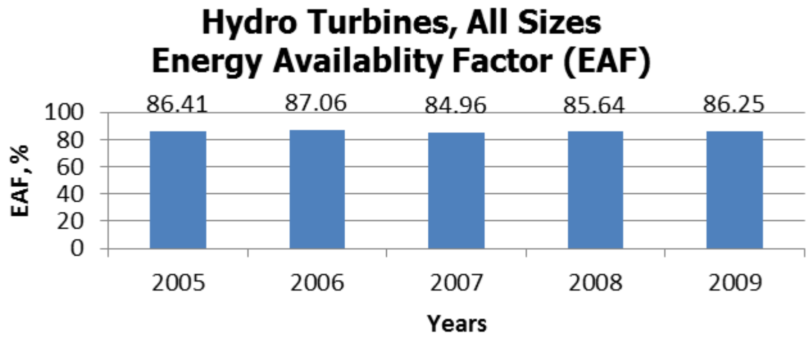


Table 2-4-J-1
Hydro Units Energy Availability Factor (EAF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF	# of Units	EAF
TOTAL	1034	86.41	957	87.06	1020	84.96	1083	85.64	1073	86.25

Table 2-4-J-2
Hydro Units Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF	# of Units	LF
TOTAL	1034	40.48	957	42.35	1020	39.14	1083	41.14	1073	40.84

Table 2-4-J-3
Hydro Units Planned Capability Loss Factor (PCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF
TOTAL	1034	8.02	957	8.00	1020	9.76	1083	7.80	1073	7.88

Table 2-4-J-4
Hydro Units Unplanned Capability Loss Factor (UCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF
TOTAL	1034	5.57	957	4.94	1020	5.28	1083	6.56	1073	5.78

Pumped Storage Units - Figure 2-4-K

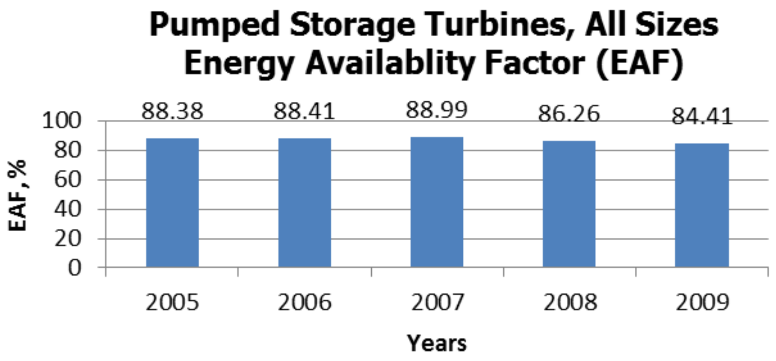


Table 2-4-K-1
Pumped Storage Units Energy Availability Factor (EAF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**
TOTAL	112	88.38	110	88.41	112	88.99	112	86.26	100	84.41

Table 2-4-K-2
Pumped Storage Units Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**
TOTAL	112	12.39	110	12.06	112	12.43	112	9.55	100	9.13

Table 2-4-K-3
Pumped Storage Units Planned Capability Loss Factor (PCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**	**# of Units**	**PCLF**
TOTAL	112	7.92	110	8.69	112	7.64	112	9.51	100	10.24

Table 2-4-K-4
Pumped Storage Units Unplanned Capability Loss Factor (UCLF)
All MW Sizes, Weighted Average per year

2005		2006		2007		2008		2009	
# of Units	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**	**# of Units**	**UCLF**

TOTAL	112	3.70	110	2.91	112	3.37	112	4.23	100	5.34

Combined Cycle Blocks
Figure 2-4-L

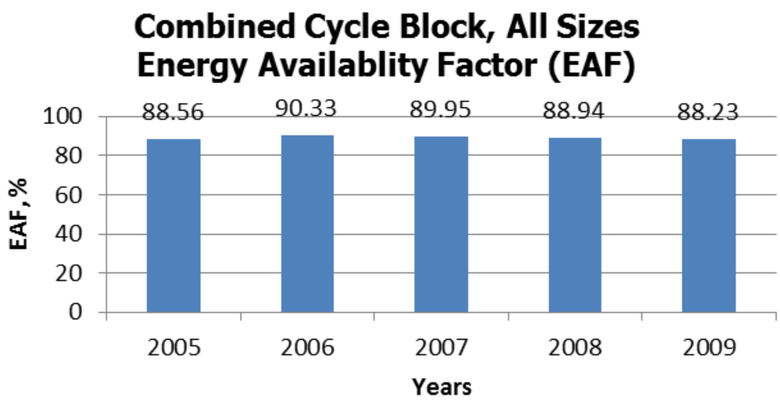


Table 2-4-L-1
Combined Cycle Block Energy Availability Factor (EAF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**	**# of Units**	**EAF**
TOTAL	135	88.56	132	90.33	146	89.95	151	88.94	166	88.23
Liquid	14	82.52	13	93.28	13	86.85	12	81.07	13	88.36
Gas	114	88.95	114	89.91	128	90.13	134	89.44	148	88.15

Table 2-4-L-2
Combined Cycle Block Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**
TOTAL	135	28.01	132	30.38	146	34.57	151	32.97	166	38.37
Liquid	14	21.26	13	22.06	13	24.55	12	11.41	13	23.89
Gas	114	28.28	114	31.12	128	35.15	134	33.87	148	38.86

Table 2-4-L-2
Combined Cycle Block Load Factor (LF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**	**# of Units**	**LF**
TOTAL	135	28.01	132	30.38	146	34.57	151	32.97	166	38.37
Liquid	14	21.26	13	22.06	13	24.55	12	11.41	13	23.89
Gas	114	28.28	114	31.12	128	35.15	134	33.87	148	38.86

Table 2-4-L-3
Combined Cycle Block Planned Capability Loss Factor (PCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF	# of Units	PCLF
TOTAL	135	5.06	132	4.42	146	5.28	151	6.60	166	6.42
Liquid	14	11.43	13	4.38	13	7.31	12	13.34	13	7.22
Gas	114	4.47	114	4.47	128	5.15	134	6.11	148	6.33

Table 2-4-L-4
Combined Cycle Block Unplanned Capability Loss Factor (UCLF)
All MW Sizes, Weighted Average per year

	2005		2006		2007		2008		2009	
	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF	# of Units	UCLF
TOTAL	135	6.39	132	4.46	146	4.77	151	4.46	166	5.35
Liquid	14	6.04	13	2.34	13	5.84	12	5.59	13	4.42
Gas	114	6.58	114	4.70	128	4.73	134	4.46	148	5.52

3. Nuclear Power Generating Units

Work Group 2

Jiri Mandula, IAEA

Introduction

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.

B hnjA 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.

The statistics presented in this 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.

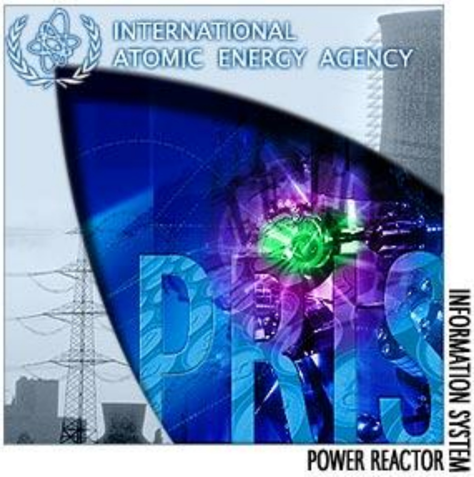
The indicators can be used for benchmarking, international comparison or analyzes of nuclear power availability and reliability from reactor specific, national or worldwide perspectives. Special care should be taken not to give priority to a single performance indicator as this could distort an objective 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.

Nuclear Power Information at the IAEA



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 3-1 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.

In the current fleet of operational power reactors the Pressurized Water Reactor (PWR) is the dominant reactor type, as shown in Figure 2. PWR units represent 66.2% of installed nuclear capacity. The PWR category includes also the Russian PWR design (VVER). The Boiling Water Reactors (BWR), including the Advanced Boiling Water Reactors (ABWR), represent 22.4% of installed capacity. Only 11.4% of installed nuclear capacity belongs to all other reactor types.

Figure 3-1: Number of reactors by region

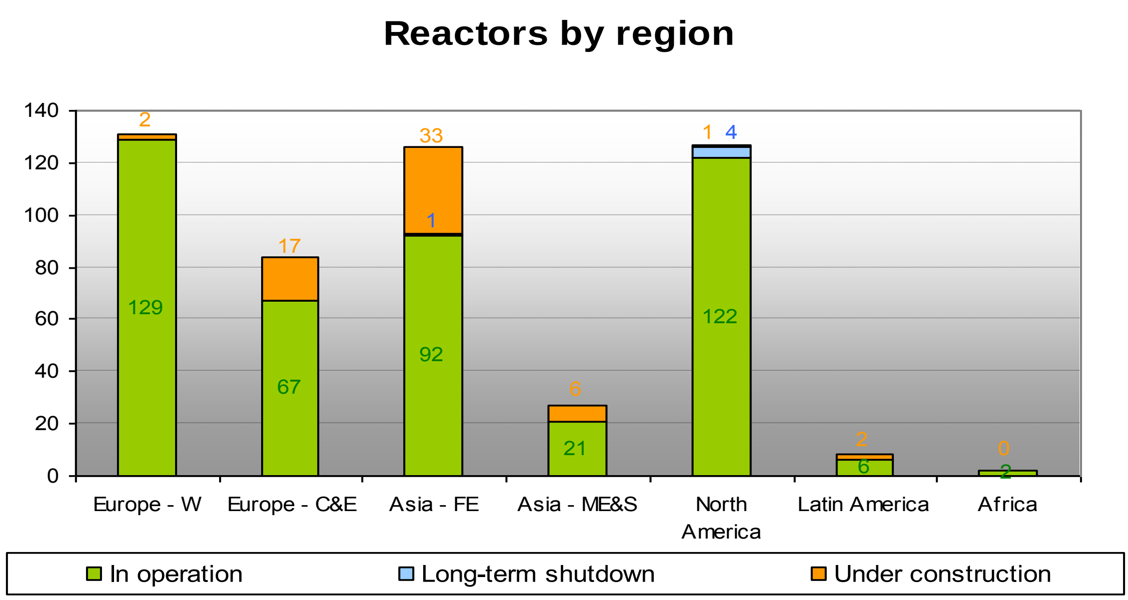


Table 3- 1: Nuclear Power Reactors in operation and under construction in the World (July 2010)

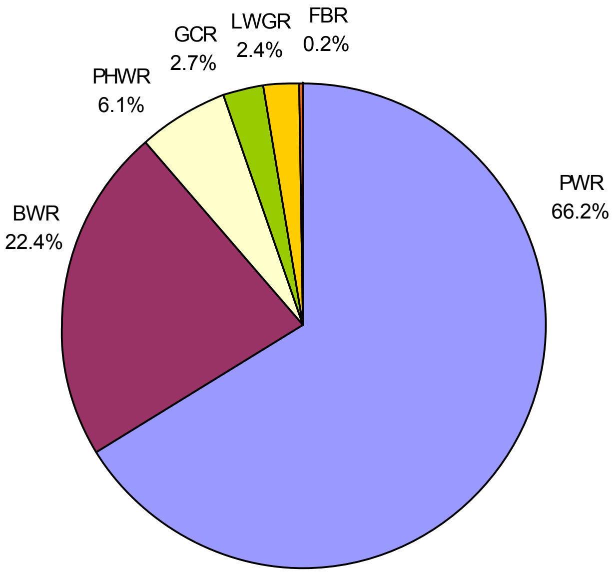
COUNTRY	Reactors in Operation		Long-term Shutdown Reactors		Reactors under Construction		Nuclear Electricity Supplied in 2009		Total Operating Experience at the end of 2009	
	No.	MWe	No.	MWe	No.	MWe	TWh	%	Year	Month
ARGENTINA	2	935			1	692	7.6	7.0	62	7
ARMENIA	1	375					2.3	45.0	35	8
BELGIUM	7	5902					45.0	51.7	233	7
BRAZIL	2	1884			1	1245	12.2	2.9	37	3
BULGARIA	2	1906			2	1906	14.2	35.9	147	3
CANADA	18	12569	4	2726			85.3	14.8	582	2
CHINA	12	9438			23	23620	65.7	1.9	99	3
CZECH REP.	6	3678					25.7	33.8	110	10
FINLAND	4	2696			1	1600	22.6	32.9	123	4
FRANCE	58	63130			1	1600	391.8	75.2	1 700	2
GERMANY	17	20480					127.7	26.1	751	5
HUNGARY	4	1889					14.3	43.0	98	2
INDIA	19	4189			4	2506	14.8	2.2	318	5
IRAN					1	915				
JAPAN	54	46823	1	246	2	2650	263.1	29.2	1 440	8
KOREA, REP. OF	20	17705			6	6520	141.1	34.8	339	7
MEXICO	2	1300					10.1	4.8	35	11
NETHERLANDS	1	487					4.0	3.7	65	0
PAKISTAN	2	425			1	300	2.6	2.7	47	10
ROMANIA	2	1300					10.8	20.6	15	11
RUSSIA	32	22693			11	9153	152.8	17.8	994	7
SLOVAKIA	4	1762			2	782	13.1	53.5	132	7
SLOVENIA	1	666					5.5	37.8	28	3
SOUTH AFRICA	2	1800					11.6	4.8	50	3
SPAIN	8	7516					50.6	17.5	269	6
SWEDEN	10	9041					50.0	37.4	372	6
SWITZERLAND	5	3238					26.3	39.5	173	10
UKRAINE	15	13107			2	1900	78.0	48.6	368	6
UK	19	10137					62.9	17.9	1 457	8
USA	104	100747			1	1165	796.9	20.2	3 499	11
Total [a,b]	**439**	**372798**	**5**	**2972**	**61**	**59154**	**2558.3**		**13 913**	**0**

Notes:

a. The total includes the following information from Lithuania and Taiwan, China:
Lithuania: 10.0 TWh of nuclear electricity generation, representing 76.2% of the total electricity; generated
Taiwan, China: 6 units, 4980 MW in operation; 2 units, 2600 MW under construction; 39.9 TWh of nuclear electricity generation, representing 20.7% of the total electricity generated.

b. The total operating experience includes also shutdown plants in Italy (81 years), Kazakhstan (25 years, 10 months), Lithuania (43 years, 6 months),), Taiwan, China (170 years, 1 month).

Figure 3-2: Distribution of nuclear capacity by reactor type



PWR is the prevailing type in all regions especially in Europe. Some reactor types like GCRs (Gas Cooled Reactors), LWGRs (Light-Water-Cooled, Graphite-Moderated Reactors), and FBRs (Fast Breeder Reactors) are currently operated only in Europe.

Development of the Nuclear Industry since 2007

Two new reactors were connected to the grid in 2009: Tomari-3 in Japan and Rajasthan-5 in India. This compares with no new connections in 2008 (first time since 1955 without a new grid connection) and three new connections in 2007 (plus one reconnection after long-term shutdown).

Three reactor units were shutdown in 2009. There was two nuclear power reactor retirements in Japan and one retirement just at the end of the year – Ignalina-2 in Lithuania.

This compares to one retirement in 2008 and no retirement in 2007. Difference in capacity of new reactors connected to the grid and shutdown reactors plus power uprating and derating of existing plants during 2007-2009 resulted in increase of the total installed capacity by 1076 MW(e).

There were 12 construction starts in 2009: nine in China, two in Russia and one in the Republic of Korea plus there was the resumption of active construction at two reactors in Slovakia whose previous classification had been ‘construction suspended’. In 2008 there were ten construction starts. In 2007 there were eight construction starts plus resumption of active construction at one reactor.

The ten countries with the highest reliance on nuclear power in 2009 were: Lithuania, 76.2%, France, 75.2%; Slovakia, 53.5%, Belgium, 51.7%; Ukraine, 48.6%; Armenia, 45.0%, Hungary, 43.0%, Switzerland, 39.5%, Slovenia 37.9% and Sweden, 37.4%.

In North America, where 122 reactors supply 20.2% of electricity in the United States and 14.8% in Canada, the number of operating reactors has increased in last three years due to re-connection of one long-term shutdown reactor units in USA (Browns Ferry 1 in 2007).

In Western Europe, with 129 reactors, overall capacity has declined by 695 MWe because of shutdown of 1 ageing reactor unit and derating of some British reactors. In Eastern and Central Europe the same number (2) of shutdowns and grid connections resulted in unchanged number of operating units (67). In Asia, with a total of 113 reactors at present, the number of operating reactors has increased by 4 since the beginning of 2007.

Trends in nuclear electricity production and capacity

Nuclear electricity production has grown almost continuously since the nuclear industry's inception. The reasons for its growth are: new capacity installation, uprating of operating plants and energy availability improvement.

From 1975 through 2009 global nuclear electricity production increased from 326 to 2556 TWh. Installed nuclear capacity rose from 72 to 373 GW(e) due to both new construction and uprates at existing facilities. Nevertheless, the global nuclear electricity generation has declined slightly in recent years. In Figure 3-3 the red bars show the growth in global nuclear electricity production since 1975 (measured against the right scale). The yellow bars show the growth in installed capacity measured against the left scale.

Different trends of installed capacity and energy production indicate that since the beginning of the 1990s, when the construction of new units slowed down, the utilization of nuclear capacity has become more efficient, nevertheless this trend has been halted in last years.

Worldwide energy availability

The basic performance indicators for this study are the Energy Availability Factor (EAF) and the Planned and Unplanned Energy Unavailability Factors (PUF and UUF). EAF is the percentage of maximum energy generation that plant was available for supply to the electrical grid. Energy unavailability is related to energy losses under and beyond plant management control when the unit is not able or not allowed to be operated at reference unit power to meet demand of the grid. Energy losses under plant management control are divided to planned and unplanned. Main contributors to planned energy losses that should be scheduled at least four weeks in advance are planned outages for refuelling, maintenance, testing and refurbishment.

Unplanned energy losses are caused mainly by outages due to equipment failures and human factors.

Figure 3- 3: Nuclear energy production

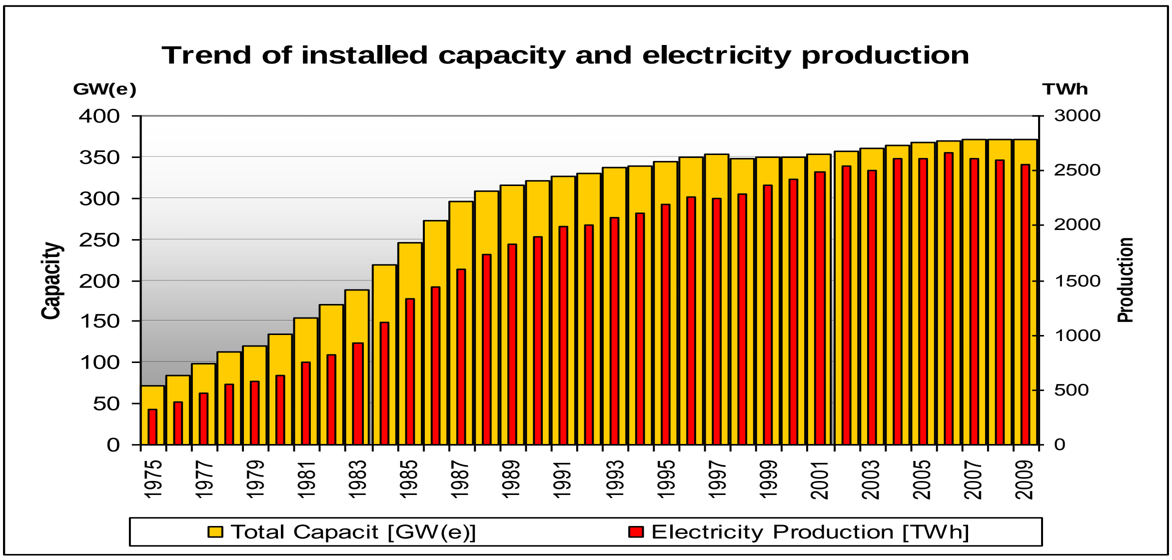
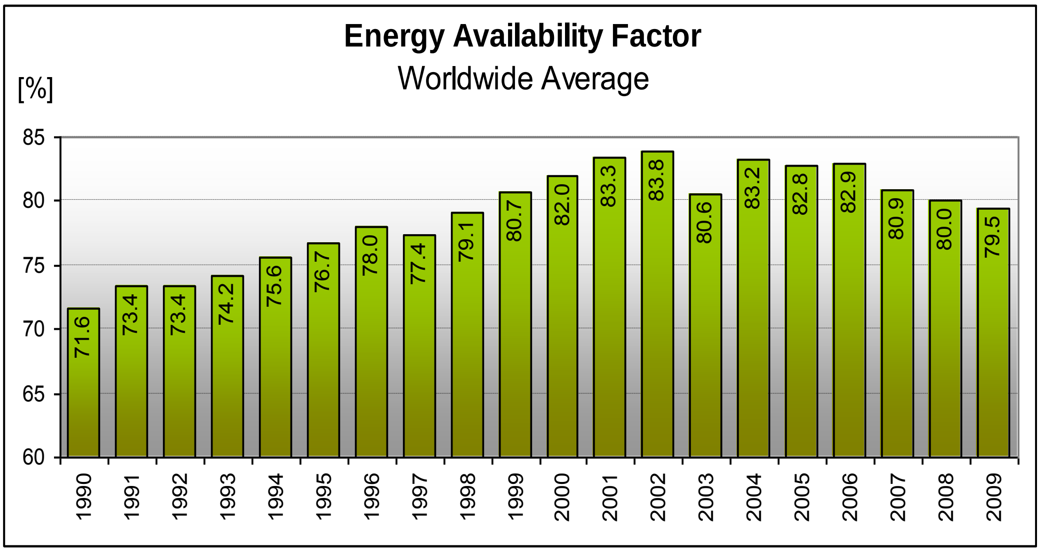


Figure 3-4: Energy Availability Factor Trend



In 2009 the worldwide EAF was 79.4% in average. Half of nuclear reactors operated with EAF above 84.9% (world-wide median value). The top quarter of reactors reached EAF above 92%. For comparison in 1990 the global energy availability factor for NPPs was 72.1% in average. The median was 76.7% and the best quartile 84.9%

The continuous increase in the EAF averaged around 1% per year in the period 1990-2002 but since 2002 this positive trend has reverted. This indication has to be analysed in details and the following break downs provide additional information that should be considered in nuclear power plant availability and unavailability analyses.

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One of the main contributing factors is plant refurbishment for long term operation. About three quarters of all reactors in operation today are over 20 years old, and one quarter are over 30 years old. Through plant life management programmes, many plants have had their original operational period extended to allow continuing operation for up to 20 additional years. Ageing reactors face the issues of materials degradation and technology obsolescence such as in instrumentation and control. Plant life management is implemented to cope with these issues in order to increase the return on investment and to extend plant licensed life.

Figure 4- 5: Distribution of reactors with the Energy Availability Factor above 70%

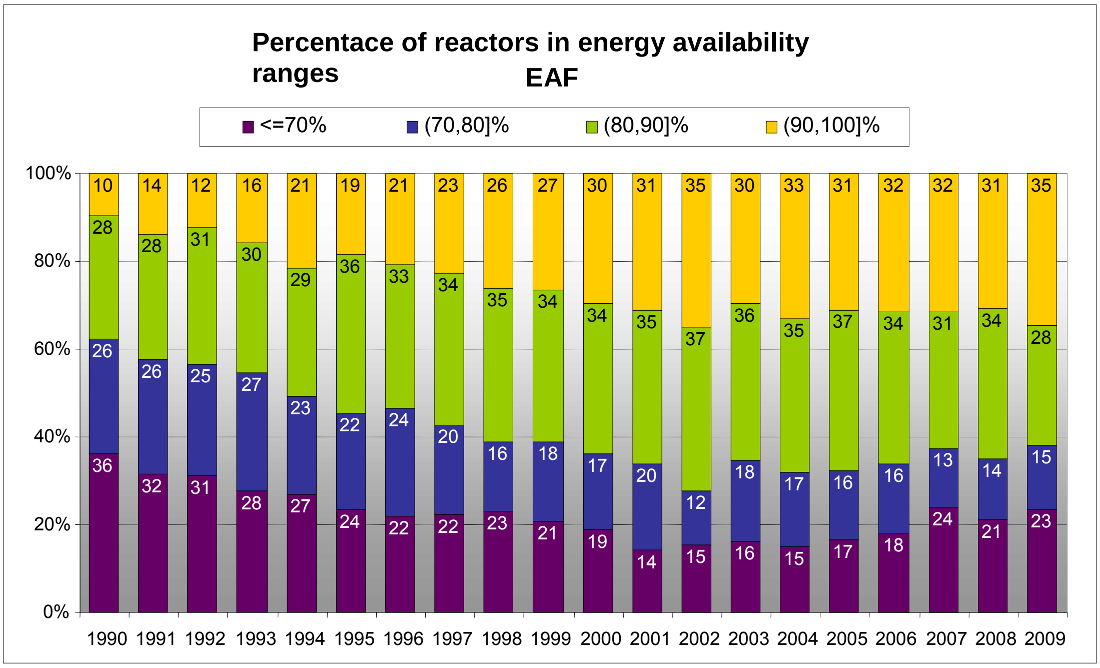
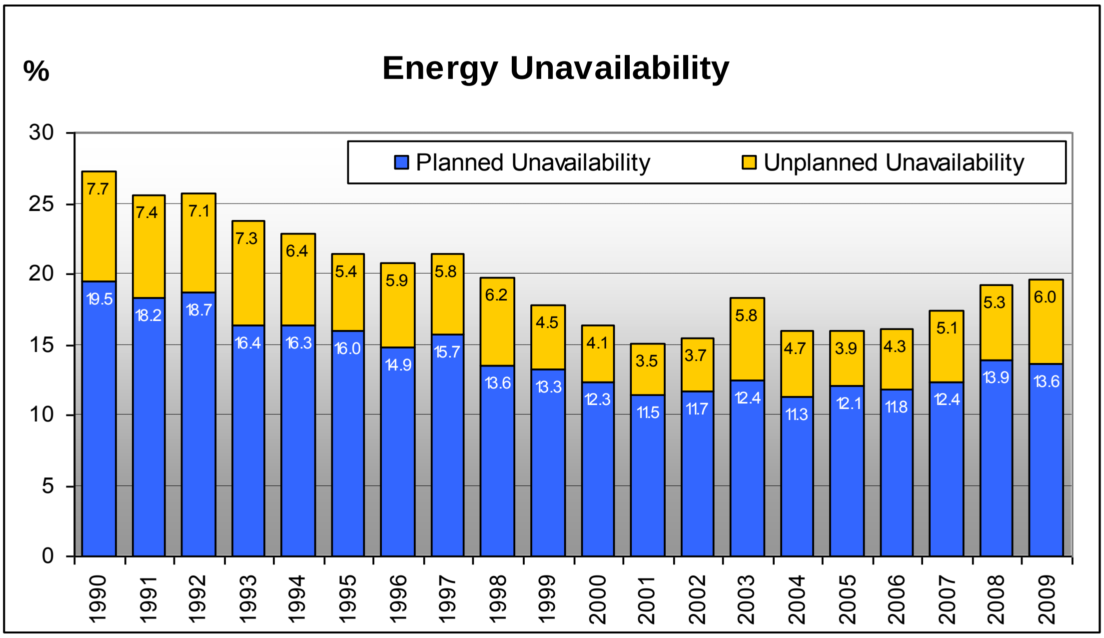


Figure 4 6: Trend of Planned and Unplanned Unavailability Factors



The number of plants presenting higher EAF (greater than 70%) provides information how EAF results are spread within the operating plants. Since 1990 the percentage of reactor units with EAF above 70% has risen from 66% to 83-86% but in last years dropped bellow 80% mainly because of increased number of not operated reactors or reactors with extended outage due to activities related to ageing management and plant license extension. The main increase was in the category 90-100%, where the percentage has risen from 10% in 1990 up to 35% in 2002 and 2009. In absolute numbers the distribution in 2009 was that out of 440 operating reactors 64 presented EAF between 70 and 79.9%, 121 reactors between 80-89.9% and 152 reactors higher than 90%.

In last seven years the steady decrease in both planned and unplanned energy unavailability factors has halted and reverted. The average planned unavailability factor decreased continuously from about of 20% at the beginning of the 1990s to 11% and was 13.6% in 2009 while the median was 9.9%. PHWR, BWR and PWR units have achieved the best results.

The improvement in the unplanned unavailability factor (UUF) was also significant. It decreased from about of 8% to 4% and was 5.5% in 2009 while the median was 1.05%.

Survey by Region

The analysis of energy availability is presented on Figure 7 by 3-year averages with double weight to a related year. It illustrates trends of energy availability factor since 1992 in world regions.

In North America the yearly EAF increased from 74% (1992) to a very high availability around 90% since 2000. This increase was mainly due to the USA units, which have improved considerably its performance in 1990s. In Western Europe, the yearly EAF has also increased since 1992, although at a lower level, from 74% in 1992 to 83% in 2000 but in last years EAF dropped down to 76%. This could be due to the uncertainties given by the different country energy policy in the region and by ageing factors of a nuclear reactor fleet.

In Eastern Europe, where the majority of units are of PWR (WWER) and LWGR (RBMK) type the EAF has increased from 62% to 80% in the last fifteen years.

The plants in Latin America have also improved the EAF from 63 to 86 % but because of low number of operating units there is a high variation in annual values. Similar variation in annual values is in Africa where only two reactor units are in operation. Improvement of availability of these two units is remarkable – from around 55% at the beginning of 1990s to values around 80% in last years.

The reactor units in the Far East improved EAF from 73% to 83% during 1990s. The trend in last seven years has been affected by long-term shutdown of 17 TEPCO plants in 2003 and 2004 and by extended shutdown of seven Kashiwazaki Kariwa reactors after the earthquake in 2007. In 2009 the EAF was 74% - still significantly less then before 2003.

In the Middle East and South Asia where currently 20 reactor units are in operation a very fast EAF improvement occurred during the second half of 1990s, when EAF increased from 45-50% to 78%. However, this reversed to a negative trend and it was only 50% in 2009. Contributing factors are extensive refurbishment of some reactor units and fuel availability in this region.

It is noteworthy that world regional analysis are difficult to make because the operating plants in such large regions are of different type, operate in different countries and under different economic and energy market conditions.

More in depth analysis should consider smaller regions or countries and other criteria used in benchmarking analysis, for instance. The determinant factors on a regional basis depend on the energy and economic situation, on the regulatory philosophy of the countries and, worldwide, the quality of the operators more than the plant location.

Survey by Reactor Type

A survey of the Energy Availability Factor by reactor type shows that there is considerable increase in the availability of reactor units in 1990s, especially for PWR, BWR, PHWR. However in last years an average availability for all reactor types except LWGR has dropped.

Figure 4-8 shows that PWR units have improved the energy availability factor from 73% in 1990 to 85% but in last three years there is a decrease to 83%. For PWR units, the planned energy unavailability factor (PUF) was 11.7% in 2009, while the unplanned energy unavailability factor (UUF) was 4.4%. The PUF median values in last three years were around 9.8%. In 2009, half of 264 PWR units operated with EAF over 86% and 94 PWR units presented EAF higher than 90%.

Since 1990, the average energy availability factor of BWR units has varied from 74.9% in 1990 to 86.4% in 2000. In recent years the availability of BWR units, especially those in Japan, was significantly affected already mentioned particular cases. In 2009 EAF dropped to 73% while half of 94 BWR units operated with EAF over 85% and 36 units presented EAF higher than 90%.

The PHWR units also increased the energy availability factor from an average of 67%, in 1990-1992, to 82% in 2004-2006. In last three years the EAF has dropped to 75.5% in 2009.

LWGR (RBMK) reactors have increased availability significantly during the last ten years. In 1992-1999 the availability was affected by longer planned outages for refurbishment and backfittings and averaged bellow 60%. Since 2000 availability has increased from 61.4% to 81% in 2009. The main area for further improvement is the management of planned maintenance as PUF is quite high. The positive trend of availability of GCR units in 1990s reversed in last ten years and has dropped from 81.6% in 2001 to 50% in 2008. In 2009 the average EAF was 68.7% and half of 18 GCR units operated with EAF over 71%

Figure 4-7: Regional trends of the Energy Availability Factor

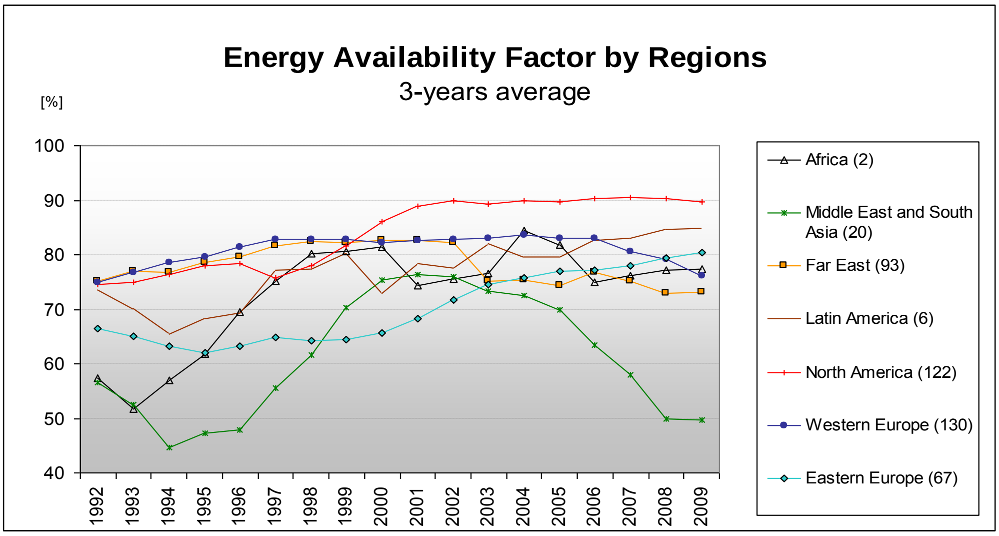
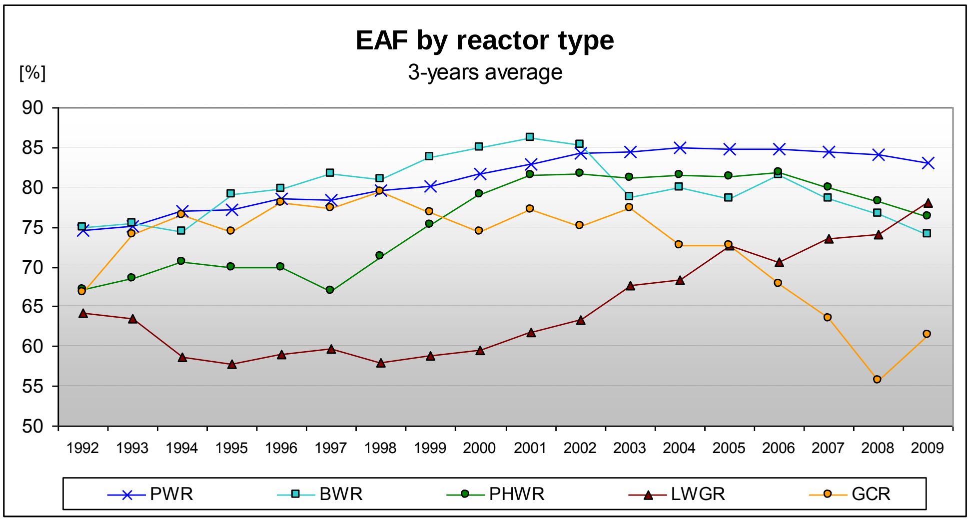


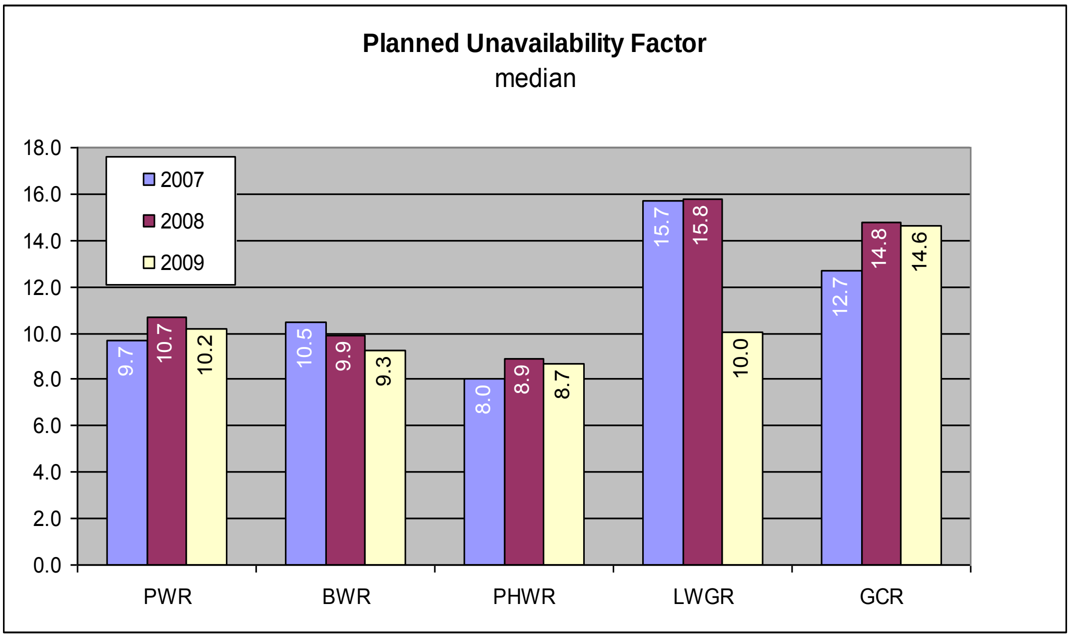
Figure 4-8: Energy Availability Factor trends for the most common reactor types



The energy losses related to planned outages are the main contributor to plant unavailability. Figure 9 shows significant differences in Planned Energy Unavailability Factors for different reactor types.

The scope, frequency and organisation of planned outages are determined in principle by reactor design (on-line and off-line refuelling) but maintenance management and optimisation is a common area for improvement.

Figure 4-9: Unavailability due to planned maintenance



outages

Conclusion

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

Currently, the global average EAF is around 80% and more then half the world's units operate with an EAF over 85%. Generally, as EAFs improve and approach 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.

Many reactor units have optimised the frequency of refuelling outages by implementing longer fuel cycles. Others have implemented improved outage strategies, which also enable shorter duration of refuelling outages. Some of them perform refuelling outages in less than two weeks, while others in more than a month. The IAEA has also assisted its Member States to exchange information on good practices for outage optimisation, improving nuclear power plant performance and other activities, which have contributed to reduction of outage duration.

The main factors contributing to improvements in reactor availability are:

- The elimination of unplanned energy losses through effective failure prevention (root cause analyses), on-line preventive maintenance, timely indications of equipment degradation, and the implementation of concurrent design improvements.
- The reduction of planned energy outages through fuel cycle extensions, effective management of refueling and maintenance outages, and risk oriented maintenance.
- The continuing exchange and dissemination of operating experiences.
- Additional consolidation in the nuclear industry so that more plants are operated by those who do it best.

The IAEA activities, which include nuclear power plant performance assessment and feedback, information exchange on outage optimization and effective quality management, are important examples of international co-operation to improve the performance of operating nuclear power plants. The World Association of Nuclear Operators (WANO) also plays an important role in maximising the safety and reliability of the operation of nuclear plants by exchanging information and encouraging communication of experience.

4. Performance Indicators for Renewable Energy Sources

Work Group 3,
Chair: Francesco Starace, Enel Green Power, Italy
Directors: Maurizio Bezzeccheri; Rafael Gonzalez Sanchez
Coordinators: Javier Vaquerizo Alonso, Ignacio Martí.

CURRENT SITUATION

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

A first phase of the work (1999-2001) proposed technical performance indicators for wind, photovoltaic, biomass and geothermal energy, as has been done in the past by WEC and UNIPEDE for nuclear and fossil-fired power plants. The second phase (2002-2004) extended the work to proposals for environmental and sociological indicators, as RES are considered particularly beneficial in terms of sustainable development. In the first phase, leading experts in RES, working with international organisations, (IEA, Eurelectric, IGA, WEC, etc.) participated in the work in order to develop standards.

Results of these first phases were presented in reports at the 18th and 19th WEC Congresses, Buenos Aires, October 2001, and Sydney, September 2004.

The third phase of the work, presented in 2008, yielded pioneering reports on wind, photovoltaic and biomass energies, completing the previous results on indicators.

During phase 3, a search was also made on the existing performance databases for RES. This was in order to see if WEC should, in a future phase, set up new databases for RES (as was done in the past for nuclear and fossil-fired power plants), or collaborate with organisations having already developing such work. In this phase we analyze the results.

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 performances.

To fulfil this objective, technical, environmental, and sociological performance indicators are necessary. The first phase of the work group has resulted in a proposal for technical indicators. Environmental and sociological indicators were proposed in the second phase.

Currently, some of these indicators are only concepts, which have yet to be more precisely defined and compared with existing or emerging norms and standards.

The development of performance indicators is the first step in a process of creating large databases which would enable power plant operators to compare their own plant performances with others, and make improvements.

During the last years it has been proven the difficulty in building proper RES performance indicators databases. We analyze in following sections the main reasons for the lack of performance data and give some headlights for future works.

STATUS OF WG3 PREVIOUS WORK. PROPOSED INDICATORS

WIND power generation

Technical performance Indicators

Table 1. Technical performance indicators. Wind Power Generation

Proposed Technical Indicators	Definitions and comments
Capacity Factor *(%)* = $\frac{\text{Total energy production during the nominal period}}{\text{Potential energy production during the period}}$ **Specific energy production** *(kWh/m²)* = $\frac{\text{Total energy production during the nominal period}}{\text{Swept rotor area}}$ **Equivalent full load hours** *(h)* = $\frac{\text{Annual energy production}}{\text{Rated power}}$ **Availability Factor** *(%)* = $\frac{\text{Total hours of operation of plant during the period x 100}}{\text{Total length of the period (hours)}}$ **Wind conditions during the period (m/s)** = Average wind speed and wind speed distribution	• **Nominal period** *(hours)* = complete period covered by the report, usually one year • **Total energy production** *(kWh)* = energy delivered at the connecting point during the monitoring (nominal) period, usually one year • **Potential energy production** *(kWh)* = rated power x monitoring (nominal) period, usually one year • **Specific energy production** *(kWh)* is also often called «**energy yield**» or «**energy productivity**», and is very much dependant on the rated power of the turbines. • **Period of non availability** *(h)* = period during which the plant is not functionning. This can be scheduled (maintenance) or not (failure, malfunction). The availability usually ranges around 95% for wind farms. • **Wind conditions** are very important to be able to compare the performances of plants (see next page)

Environmental Performance Indicators

Table 1. Environmental performance indicators. Wind Power Generation

Proposed Environmental Performance Indicators	Samples and comments
General indicators *(also applicable to other types of power plants)*	
Contribution to the reduction of greenhouse gas emissions : **AvCO2 (t/MW/y)** = avoided CO2 emissions (in metric tonnes per MW per year), compared to what would have been emitted by a new plant built in the region, given the same annual production (in kWh), using as fuel the most likely future fuel choice, or by the plant most likely to be displaced by the new RES facility (usually the oldest plant scheduled for retirement)	* Total European wind farms (16300 MW) avoid 30 million tons CO_2 / year (source ADEME France) * WindPower Denmark : avoided CO_2 = 2000 t /MW/year * US AWEA : 750 kW wind turbine avoids 1500 t CO_2 / year ***Comment*** : the reference technology displaced must be quoted (coal, oil, gas).
Pollutant emissions during the life cycle (g / kWh) : Q_{CO2}, Q_{SOx}, Q_{NOx} **(g/kWh)** = quantities of CO2, SOx and NOx emitted per kWh during the whole life cycle of the plant	Q_{CO2} = 7 - 9 g / kWh Q_{SOx} = 0.02 – 0.09 g / kWh Q_{NOx} = 0.02 – 0.06 g / kWh *(Source IEA, Benign Energy ?, The Environmental Implication of Renewables, OECD Paris, 1998)*
Specific indicators	
Visual effects / Landscape protection distance (m) : d_{min} **(m)** = Minimum distance away from nearby dwellings	France recommends a minimum distance of 500 m
Noise from wind turbines (dB) : S_f = Maximum noise (dB) at the foot of the wind turbines S_{500} = Maximum noise (dB) 500 m away from the wind turbines S_{st} = Maximum noise (dB) at standard distance H + D/2 according to norm IEC 61400-11	- EDF recommends S_{500} lower than 35 dB - Nordex 2.5 MW = 102.8 dB(A) at hub for a 8m/s wind - For most turbines, $S_f < 55$ dB - WT 2 MW : S_{500} = 39.7 dB and S_{250} = 48.2 dB (source Systèmes Solaires)
Birds fatalities (n/y) : **Nb** = Number of birds killed per wind turbine per year	Nb = 0.4 to 1.3 average Europe Nb = 5.2 average California

Social Performance Indicators

Table 2. Sociological performance indicators. Wind Power Generation

Proposed Sociological Indicators	Samples and comments
- Jobs created by the plant (n/MW) : **Nj** = number of jobs (direct / indirect) created by a 1 MW power plant for the different steps : manufacture, installation, operation and maintenance.	• Beware of **subsidies** in some countries which can distort the data and prevent meaningful comparisons. • A **distinction** must be made between job-years for **manufacturing** and **installation** on one hand, and jobs for **O&M** on the other hand, especially when the manufacturer is not in the country of installation. • A European study of 1999 assumes that 17 job–years of employment are created for every MW of wind energy capacity manufactured, and a further 5 job – years for the installation of every MW, bringing the total to 22 job - years. • The latest update of *Wind Force 12* (EWEA, 2003a) suggests that the feasible number of jobs created in the wind industry worldwide by 2020 will be 1.8 million.
- Providing access to electricity : **Na** = number of households / total number of people having now access to the electricity produced by a 1 MW plant, and who would not have such access if another type of plant were to be built (grid connected).	***Recall*** : we have chosen in the study to focus only on grid-connected plants. In developing countries, isolated wind turbines may bring power to people who may not, otherwise, have access to electricity at all without them. • WindPower Denmark : 1 MW wind energy provides electricity to 500 to 800 households in Europe. • Edens Italy : a wind plant rated 1 MW can provide electricity for 1000 houses (without heating)
- Industrial Safety Accident Rate : **SAR** = number of accidents for all utility personnel permanently assigned to the plant (contractor personnel not included), that result in one or more days away from work (excluding the day of the accident) or one or more days of restricted work (excluding the day of the accident), or fatalities, per 1,000,000 man-hours worked.	• This indicator is already widely used for other conventional types of power plants (nuclear, fossil-fired, etc…). • The purpose of this indicator is to monitor progress in improving industrial safety performance for all utility personnel permanently assigned to the utility's staff. • This indicator was chosen as the personnel safety indicator over other indicators, such as injury rate or severity rate, because the criteria are clearly defined, utilities currently collect this data, and the data are the least subjective.

PHOTOVOLTAIC POWER GENERATION

Technical Performance Indicators

Table 3. Technical performance indicators. PV Power Generation

Technical Performance Indicators	Definitions
• **Reference Yield, Y_R** $Y_R = \frac{E_{S,A} \ [kWh/(m^2 \cdot d)]}{G_{STC} \ [kW/m^2]}$	The **Reference yield** Y_R is the daily (monthly or annual) in-plane irradiation $E_{S,A}$ divided by the STC reference in-plane irradiance G_{STC} (= 1 kW/m²) It has the dimension *h/d* and can be considered as the number of hours per day during which the solar radiation would be at reference irradiance level, in order to contribute the same energy incident as was monitored.
• **Array Yield, Y_A** $Y_A = \frac{E_{A,d} \ [kWh/d]}{Po \ [kWp]}$	The **Array yield** Y_A is the daily (monthly or annual) array energy output $E_{A,d}$ per kWp of installed PV array power *Po* It has the dimension *kWh/(d · kWp)* and can be considered as the number of hours of array operation per day at *Po*, which would give the same energy output as the recorded integral value for that day (month or year).
• **Final Yield, Y_F** $Y_f = \frac{E_{use} \ [kWh/d]}{Po \ [kWp]}$	The **Final yield** Y_f is the daily (monthly or annual) plant useful energy output E_{use} per kWp of installed PV array power *Po*: It has the dimension *kWh/(d · kWp)* and can also be considered as the number of hours of plant operation per day at *Po*, which would give the same energy output as the recorded integral value for that day (month or year).
• **Performance Ratio, PR** $PR = \frac{Y_f}{Y_R}$	The **Performance Ratio**, *PR* indicates the overall effect of losses on array's rated output due to array temperature, incomplete utilisation of the irradiation, and system component inefficiencies or failures.

Environmental Performance Indicators

Table 4. Environmental performance indicators. PV Power Generation

Proposed Environmental Performance Indicators	Samples and comments
General indicators *(also applicable to other types of power plants)*	
Contribution to the reduction of greenhouse gas emissions **AvCO2 (t/MW/y)** = avoided CO2 emissions (in metric tonnes per MW per year), compared to what would have been emitted by a new plant built in the region, given the same annual production (in kWh), using as fuel the most likely future fuel choice, or by the plant most likely to be displaced by the new RES facility (usually the oldest plant scheduled for retirement). --- **Pollutant emissions during the life cycle (g / kWh)** : Q_{CO2}, Q_{SOx}, Q_{NOx} **(g/kWh)** = quantities of CO2, SOx and NOx emitted per kWh during the whole life cycle of the plant	This indicator must take into account CO2 content of electricity used for manufacture of cells (manufacture nearly needs as much energy as will be produced during 2 to 3 years – lifetime of a cell = 20 to 25 years). The amount of CO2 will depend on the fuel mix of the country where the PV cells are manufactured. --- Q_{CO2} = 98 - 167 g / kWh Q_{SOx} = 0.2 – 0.34 g / kWh Q_{NOx} = 0.18 – 0.30 g / kWh *(Source IEA, Benign Energy ?, The Environmental Implication of Renewables, OECD Paris, 1998)*
Specific indicators	
Qtox (g/Wp) = Quantities of toxic materials contained in the cells and batteries, that will have to be recycled or disposed of after the lifetime of the cells and batteries (Cd, etc …)	The duration of operation to produce the energy consumed for the manufacturing of the PV modules could be an additional indicator. However, on one hand the PV cells are very often not used in the country where they have been manufactured, and on the other hand the operation of the PV plant can be very different from one place to another, and therefore very difficult to compare.

Social Performance Indicators

Table 5. Sociological performance indicators. PV Power Generation

Proposed Sociological Indicators	Samples and comments
- Jobs created by the plant (n/MW) : **Nj** = number of jobs (direct / indirect) created by a 1 MW power plant for the different steps: manufacture, installation, operation and maintenance.	• Beware of **subsidies** in some countries which can distort the data and prevent meaningful comparisons. • A **distinction** must be made between job-years for **manufacturing** and **installation** on one hand, and jobs for **O&M** on the other hand, especially when the manufacturer is not in the country of installation. • Estimate by CEA-France 2003 : 20 jobs per produced MW, 30 jobs per consumed MW • SEIA (Solar Energy Industry Association – USA) → 3,800 jobs created for every $ 100 million of PV cell sales.
- Providing access to electricity : **Na** = number of households / total number of people having now access to the electricity produced by a 1 MW plant, and who would not have such access if another type of plant were to be built (grid connected).	***Recall*** : we have chosen in the study to focus only on grid-connected plants. In developing countries, isolated PV modules may bring power to people who may not, otherwise, have access to electricity at all without them
- Industrial Safety Accident Rate : **SAR** = number of accidents for all utility personnel permanently assigned to the plant (contractor personnel not included), that result in one or more days away from work (excluding the day of the accident) or one or more days of restricted work (excluding the day of the accident), or fatalities, per 1,000,000 man-hours worked.	• This indicator is already widely used for other conventional types of power plants (nuclear, fossil-fired, etc…) • The purpose of this indicator is to monitor progress in improving industrial safety performance for all utility personnel permanently assigned to the utility's staff. • This indicator was chosen as the personnel safety indicator over other indicators, such as injury rate or severity rate, because the criteria are clearly defined, utilities currently collect this data, and the data are the least subjective.

BIOMASS power generation

Technical Performance Indicators

Table 6. Technical performance indicators. Biomass Power Generation

Proposed Technical Performance Indicators	Comments
Efficiency (Higher Heat Value HHV) = $\frac{\text{Net output in heat unit}}{\text{Fuel heat input}}$	• **Efficiency** = Net output in heat unit equivalent of the electricity, divided by the fuel heat input using the higher heating value of the fuel
Fuel moisture = $\frac{\text{Moisture (H2O)}}{\text{Total weight of fuel}}$	• **Fuel moisture** = Moisture (H2O) as a fraction of the total (wet, not dry basis) weight of fuel
Capacity Factor (%) = $\frac{\text{Total net electricity generation during the period (MWh) x 100}}{\text{Plant size (net MW) x Total length of period (hours)}}$	• **Capacity Factor** = Capability Factor used for «classical» fossil-fired power plants
Availability Factor (%) = $\frac{\text{Total hours of operation of plant during the period x 100}}{\text{Total length of period (hours)}}$	
Hours per year equivalent of the capacity factor = Number of hours that would give the net annual generation if all operations were at full power of plant	

Environmental Performance Indicators

Table 7. Environmental performance indicators. Biomass Power Generation

Proposed Environmental Performance Indicators	Samples and comments
General indicators *(also applicable to other types of power plants)*	
Contribution to the reduction of greenhouse gas emissions **AvCO2 (t/MW/y)** = avoided CO2 emissions (in metric tonnes per MW per year), compared to what would have been emitted by a new plant built in the region, given the same annual production (in kWh), using as fuel the most likely future fuel choice, or by the plant most likely to be displaced by the new RES facility (usually the oldest plant scheduled for retirement). -- **Pollutant emissions during the life cycle (g / kWh)** : Q_{CO2}, Q_{SOx}, Q_{NOx} **(g/kWh)** = quantities of CO2, SOx and NOx emitted per kWh during the whole life cycle of the plant	When managed in a sustainable cycle (energy crops, replanting harvested areas, etc…), biopower generation can be viewed as a way to recycle carbon, and can be considered a carbon – neutral power generation option. -- For energy crops (current practice) : Q_{CO2} = 17 - 27 g / kWh Q_{SOx} = 0.07 – 0.16 g / kWh Q_{NOx} = 1.1 – 2.5 g / kWh *(Source IEA, Benign Energy ?, The Environmental Implication of Renewables, OECD Paris, 1998)*
Specific indicators	
Q_{ash} **(g/kWh)** = Quantities of ash emitted, with their composition (Se, Pb, As, B …?) → cf. in particular agricultural residues, wood wastes, animal wastes, energy crops. Q_{CH4} **(g/kWh)** = Quantities of **CH4** emitted from landfills (decomposition of biomass material) or decomposing animal manure (land-applied or left uncovered in a lagoon)	Biomass is a large and complex subject. Impacts on many natural features need to be carefully examined case by case; it is difficult to establish a few general criteria. For example, wood-processing wastes could be different from lumberyards' waste, agricultural waste, forest detritus, or energy farm trees. Impacts could be different in wetlands, desert or arid areas, forest lands, prairies, etc. The type of biomass and conditions of use must then be described carefully if we want to make useful comparisons

Social Performance Indicators

Table 8. Sociological performance indicators. Biomass Power Generation

Proposed Sociological Indicators	Samples and comments
- **Jobs created by the plant (n/MW) :** **Nj** = number of jobs (direct / indirect) created by a 1 MW power plant for the different steps: manufacture, installation, operation and maintenance.	• In France, the estimate is 4,5 direct jobs created for 1,000 tep (tonnes equivalent petroleum) produced or distributed , which means about 2 jobs / MW . • In the USA, EPRI gives an average value of about 20 full-time operating and supervising staff members for a 20 MW biomass power plant. Altogether (including operation, maintenance, truck drivers, etc …), a total of 1.6 jobs per MW is estimated by EPRI in the USA.
- **Providing access to electricity :** **Na** = number of households / total number of people having now access to the electricity produced by a 1 MW plant, and who would not have such access if another type of plant were to be built (grid connected).	***Recall*** : we have chosen in the study to focus only on grid-connected plants. In developing countries, biomass may bring power to people who may not, otherwise, have access to electricity at all without it.
- **Industrial Safety Accident Rate :** **SAR** = number of accidents for all utility personnel permanently assigned to the plant (contractor personnel not included), that result in one or more days away from work (excluding the day of the accident) or one or more days of restricted work (excluding the day of the accident), or fatalities, per 1,000,000 man-hours worked.	• This indicator is already widely used for other conventional types of power plants (nuclear, fossil-fired, etc…). • The purpose of this indicator is to monitor progress in improving industrial safety performance for all utility personnel permanently assigned to the utility's staff. • This indicator was chosen as the personnel safety indicator over other indicators, such as injury rate or severity rate, because the criteria are clearly defined, utilities currently collect this data, and the data are the least subjective.

GEOTHERMAL power generation

Technical Performance Indicators

Table 9. Technical performance indicators. Geothermal Power Generation

Proposed Technical Performance Indicators	Comments
Capacity Factor = $\frac{\text{Total MWh generated in period x 100}}{\text{Installed Capacity (Mwe) x period (hours)}}$ **Load Factor** = $\frac{\text{Total MWh generated in period x 100}}{\text{Maximum Load (Mwe) x period (hours)}}$ **Availability Factor** = $\frac{\text{Total hours of operation of plant during the period x 100}}{\text{Total Length of period (hours)}}$	• Both **Capacity and Load Factors** are needed to describe the technical performance of the plant. Where they are approximately the same, this is an indication that the installed capacity is equal to both the field conditions and the market conditions. On the other hand, where the Capacity Factor is significantly lower than the Load Factor, this is a sign that the installed capacity is too large either for the geothermal field or the market. •The **unavailability** (%) of the plant (100-availability factor) is split into two categories : **Planned outage** - An outage scheduled well in advance (at least two weeks) of the actual outage. **Forced outage** - Unplanned outage that requires the plant to be taken out of service immediately or before the next planned outage.

Environmental Performance Indicators

Table 10. **Environmental performance indicators. Geothermal Power Generation**

Proposed Environmental Performance Indicators	Samples and comments
General indicators *(also applicable to other types of power plants)*	
Contribution to the reduction of greenhouse gas emissions **AvCO2 (t/MW/y)** = avoided CO2 emissions (in metric tonnes per MW per year), compared to what would have been emitted by a new plant built in the region, given the same annual production (in kWh), using as fuel the most likely future fuel choice, or by the plant most likely to be displaced by the new RES facility (usually the oldest plant scheduled for retirement). -- **Pollutant emissions during the life cycle (g / kWh)** : Q_{CO2}, Q_{SOx}, Q_{NOx} **(g/kWh)** = quantities of CO2, SOx and NOx emitted per kWh during the whole life cycle of the plant	* 700 MW geothermal avoids 13 million tons of CO2 in 20 years (i.e. 930 t / MW / year) *(source ORMAT)* -- •**CO2** is NOT produced from the human-induced exploitation, but they are NATURAL gas, generated from deep chemical reactions; they are naturally released to the atmosphere in all geothermal/volcanic areas. The natural CO2 soil degassing from a standard geothermal area is of the same order of magnitude of the gas emitted from a geothermal power plant. Geothermal energy does not create new CO2 molecules, but simply concentrates at the chimney the natural emission from deep underground layers •**SOx and NOx** are not present in the geothermal fluid ; only a minor production could be released from the diesel engines during the drilling activity, but is –of course- very limited and not relevant during the production life of the plant
Specific indicators	
Q_{H2S} **(g/kWh)** = Emissions of H2S during the life cycle of the plant, in g per kWh	* 1 g H_2S / kWh * H_2S is 1% in volume of the CO2 released : this is a rough world-wide average *(Source : International Geothermal Association (IGA))*

Social Performance Indicators

Table 11. **Environmental performance indicators. Geothermal Power Generation**

Proposed Sociological Indicators	Samples and comments
- **Jobs created by the plant (n/MW) :** **Nj** = number of jobs (direct / indirect) created by a 1 MW power plant for the different steps: manufacture, installation, operation and maintenance.	• Beware of **subsidies** in some countries which can distort the data and prevent meaningful comparisons. • A **distinction** must be made between job-years for **manufacturing** and **installation** on one hand, and jobs for **O&M** on the other hand, especially when the manufacturer is not in the country of installation. • The number of jobs is not always related to the number of MW. For example, for **geothermal plants**, there is no difference related to the unit size. For each standard Unit (15-30-55 MW) there is a direct O&M personnel of about 30. The indirect personnel is very difficult to estimate: taking into account the construction phase of each component, drilling of wells, building the plant, and the resource assessment researcher, we can easily account for 100/200 jobs related to each geothermal unit, even if for a limited time.
- **Providing access to electricity :** **Na** = number of households / total number of people having now access to the electricity produced by a 1 MW plant, and who would not have such access if another type of plant were to be built (grid connected).	• 30-40,000,000 people are now having access to geothermal electricity in the world
- **Industrial Safety Accident Rate :** **SAR** = number of accidents for all utility personnel permanently assigned to the plant (contractor personnel not included), that result in one or more days away from work (excluding the day of the accident) or one or more days of restricted work (excluding the day of the accident), or fatalities, per 1,000,000 man-hours worked.	• This indicator is already widely used for other conventional types of power plants (nuclear, fossil-fired, etc…). • The purpose of this indicator is to monitor progress in improving industrial safety performance for all utility personnel permanently assigned to the utility's staff. • This indicator was chosen as the personnel safety indicator over other indicators, such as injury rate or severity rate, because the criteria are clearly defined, utilities currently collect this data, and the data are the least subjective.

BENCHMARKING AS OBJECTIVE: REVIEW OF DATABASES

The aim of PGP working group for renewables is to set up databases for RES, as it was done in the past for more "classical" power plants in order to enable people to compare themselves and improve their performances. During last years of work, a lot of general RES databases have been found 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 normalized definition for the most important ones. As an example there is an IEC working group, set up in 2007, with the aim of producing a standard to outline a common definition of availability down time categories for wind power plants. Up to now there remains no international agreed definition of Availability. Further detailed key performance indicators definitions are necessary (involving international organizations IEC/ISO).

There are few databases devoting to the performance of renewable plants and they are not well updated (Wind Stats Newsletter for wind, IEA-PVPS Task 2 for PV, 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 clear: RES business model is not comparable to conventional generation plants one.

- 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 definition not well standardized
- Owners do not always have "utility" mind
- Heavy competition: companies are hesitant in providing information.
- "Young" business. RES companies mainly oriented to development, not to operational excellence.
- Promoters "population" highly fragmented (small investors, land owners, banks, real state, utilities)
- Technical difficulties to overcome
- Several generation units per plant (i.e. wind). A lot of data required for simple plant analysis.
- Data management is hard for a medium size promoter dealing with different technology and different data formats in each single plant.
- Generally extreme condition locations. Complicated access, Communications trouble 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 report. In most of the cases only a regulatory framework in which performance data gathering is mandatory can ensure the existence of proper databases.

The future phases of RES WEC Working Group should re-define procedures focusing on standardization of data gathering and KPI calculation definition for RES, before dealing with databases creation, involving normalization agencies, manufacturers, technological associations, lobbies and RES consultants in addition to promoters. This new approach is a medium-long term target taking into consideration the maturation timeframe of RES.

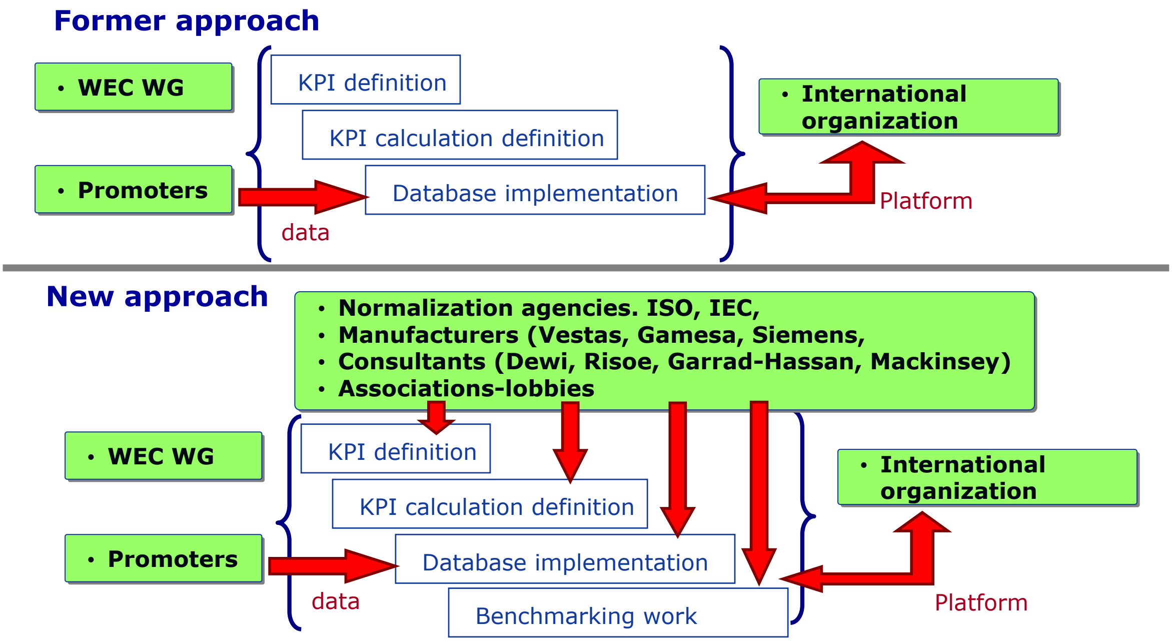


Figure 1. **WG3 new approach to KPI databases construction**

In spite of difficulties new projects are under development in order to deal with RES performance indicators databases issues. The more advanced one is a database under construction at NERC USA for wind (GADS – co-ordinated by Mike Curley, chairman of WEC PGP WG2).

Case study. NERC GADS Wind

GADS is a voluntary industry program, open to all participants in the Regional Entities and any other organization (domestic or international) that operate wind turbine generating facilities. Although GADS is a voluntary program, participating organizations must be prepared to commit the necessary effort to provide timely, accurate, and complete data. These reporting instructions detail the data elements collected by GADS and have been identified by the industry as being vital to the understanding and interpretation of wind turbine performance.

NERC is now negotiating with USA federal authorities in order to define a new legal framework that will enable NERC shifting the program from voluntary to mandatory.

There are near 100 members of the Wind Turbine Working Group including Owners/operators, ISO, PUC and Wind organizations (UWIG, AWEA). The structure of database has been defined with the following Data Reporting Instructions:

- Description of hierarchy (plants, groups and sub-groups)
- Terms and definitions of outage types (performance reporting)
- Categories of equipment associated with outages (component outage reporting)
- Equations for performance measures
- Examples of outage reporting

NERC has developed the Wind Generation Data Entry software to assist with the collection of wind generation data. The software along with the accompanying Wind Generation Data Entry Software User Manual is available free of charge from NERC's web site: **http://www.nerc.com/page.php?cid=4|43|46**

HIERARCHY ENTITIES

Plants

A plant is defined as a collection of wind turbine groups at a single physical location. There may be any number of wind turbine groups at a wind plant. The plant data only needs to be provided to NERC once when you begin to report data for each plant.

Groups

A group is one or more sub-groups that are connected to a common revenue meter. There may be any number of groups per wind plant. Each group has a unique number that identifies it as part of a particular wind plant. Each group will have a unique turbine group ID that will be associated with its child sub-group. This ID is assigned by the reporting utility.

Sub-Groups

A sub-group is a collection of wind turbine machines with the same manufacturer, designs, model number and phase of construction. This data collection is a one-time event and it is strongly encouraged to follow the recommended guidelines mentioned. Each sub-group will have a unique identifier and be associated with its parent group. Component outage and performance data will be collected at this level.

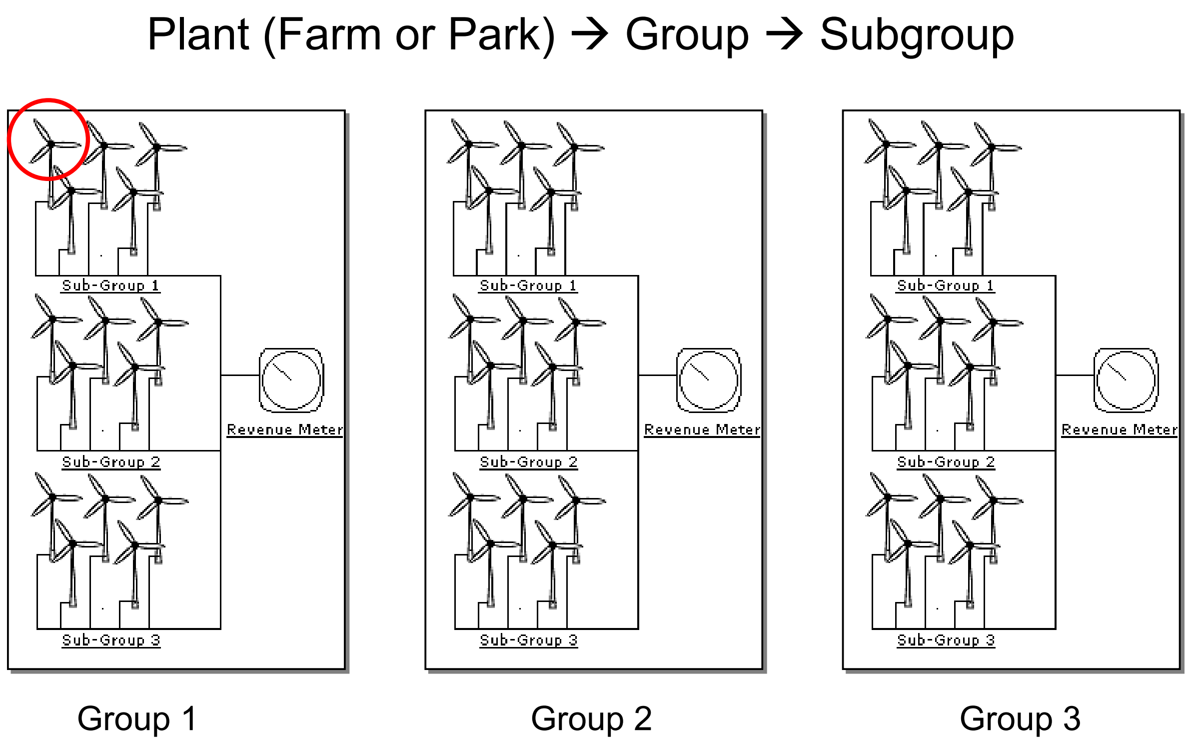


Figure 2. NERC GADS WIND. Hierarchy entities definition

Wind Turbine Groups. Detailed Data:

Plant ID - a unique ID to the plant that you are reporting. This ID is referenced in all groups, sub-groups, performance, and component data existing under the plant.

Group ID - Enter a unique ID to the group that you are reporting. This ID is referenced in all sub-groups, performance data, and hours' data existing under the group.

Group Name - the name given to the group that you are reporting.

NERC Utility Code - the three character alpha-numeric code NERC assigned to your utility. Appendix B contains a complete list of the utilities participating in GADS and their assigned utility codes.

NERC Unit Code - the three character alpha-numeric code your utility assigned for the unit that you are reporting. This code distinguishes one unit from another in your utility. Appendix B contains a guide for selecting unit codes.

ISO Resource ID - the unique identifier given to the group by the ISO.

Capacity - the total capacity for the entire group, measured in megawatts (MW).

Auxiliary Capacity - the combined capacities for all the auxiliary turbines not normally connected, and not part of GIC, measured in megawatts (MW).

Commercial Date - the date (MM/DD/YYYY), that the group came online and entered into active status.

Country - the two-letter country abbreviation where the group is located

Nearest City - the name of the city closest in proximity to the group.

State /Province - the two-letter state/province abbreviation where the group is located.

Longitude - the degrees of longitude of the physical location of the group.

Latitude - the degrees of latitude of the physical location of the group.

Elevation - the elevation of the physical location of the group, given in meters.

Wind Regime - the average topography of the area in which the group is located

Annual Average Wind Speed - the annual average wind speed (AAWS) at 80m, measured in meters per second

SCADA Type - the type of SCADA system being used.

SCADA Manufacturer

SCADA Model

Wind Turbine Sub Groups. Detailed Data:

Plant ID - a unique ID to the plant that you are reporting. This ID is referenced in all groups, sub-groups, performance, and component data existing under the plant.

Group ID - a unique ID to the group that you are reporting. This ID is referenced in all sub-groups, performance data, and hours data existing under the group.

Sub-Group ID - a unique ID to the sub-group that you are reporting. This ID is referenced in all performance and component data existing under the sub-group.

NERC Utility Code - the three character alpha-numeric code NERC assigned to your utility. Appendix B contains a complete list of the utilities participating in GADS and their assigned utility codes.

NERC Unit Code - the three character alpha-numeric code your utility assigned for the unit that you are reporting. This code distinguishes one unit from another in your utility. Appendix B contains a guide for selecting unit codes.

Sub-Group Number - The sub-group number identifies all the individual sub-groups within a parent group. Each sub-group is assigned a unique code as they are entered starting with 1 through 999. If you have two groups, Group A having 2 sub-groups and Group B having 3 sub-groups, the sub-groups associated with Group A would be numbered 1 and 2, while the sub-groups associated with Group B would be numbered 1, 2, and 3.

Sub-Group Name - the name given to the sub-group that you are reporting.

Commissioning Year - the year (YYYY), that the sub-group was commissioned.

Typical Nameplate Capacity - the individual turbine capacity, or megawatt (MW) rating, of the typical wind turbine in the group. For example, if your subgroup is made up of twenty 1.5 MW turbines you would enter 1.5 MW.

Total Number of Turbines - the actual number of physical turbines that exist in the sub-group. For example, if your subgroup is made of twenty turbines you would enter 20.

Manufacturer - the name of the manufacturer of the turbines in the sub-group. See Appendix F.

Make - the name of the make of the turbines in the sub-group.

Model - the model name of the turbines in the sub-group.

Rotor Height - the height of the rotor hub, given in meters.

Rotor Diameter - the diameter of the rotor, given in meters.

Cut-in Wind Speed - the lowest wind speed that the turbine will start to generate power, in meters per second.

Low Cut-out Wind Speed - the lowest wind speed that the turbine can continue to generate power before cutting out, in meters per second

High Cut-out Wind Speed - the highest wind speed at which the turbine is capable of generating power before cutting out, in meters per second.

Turbulence

Wind Speed Range - the average range of wind speed where the sub-group is located, measured in meters per second

Wind Shear - the average strength of the difference between wind speeds from the tip of the rotor at its lowest point and its highest point.

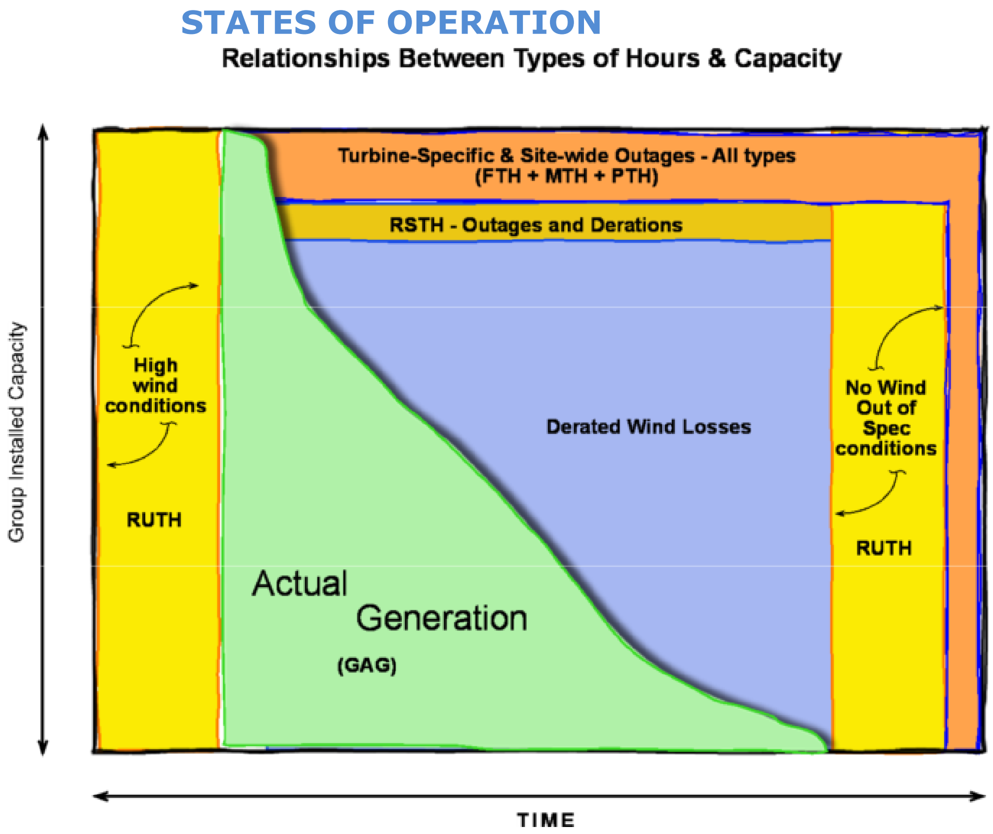


Figure 3. **Relationships Between Types of hours &Capacity**

Time spent in various units states:

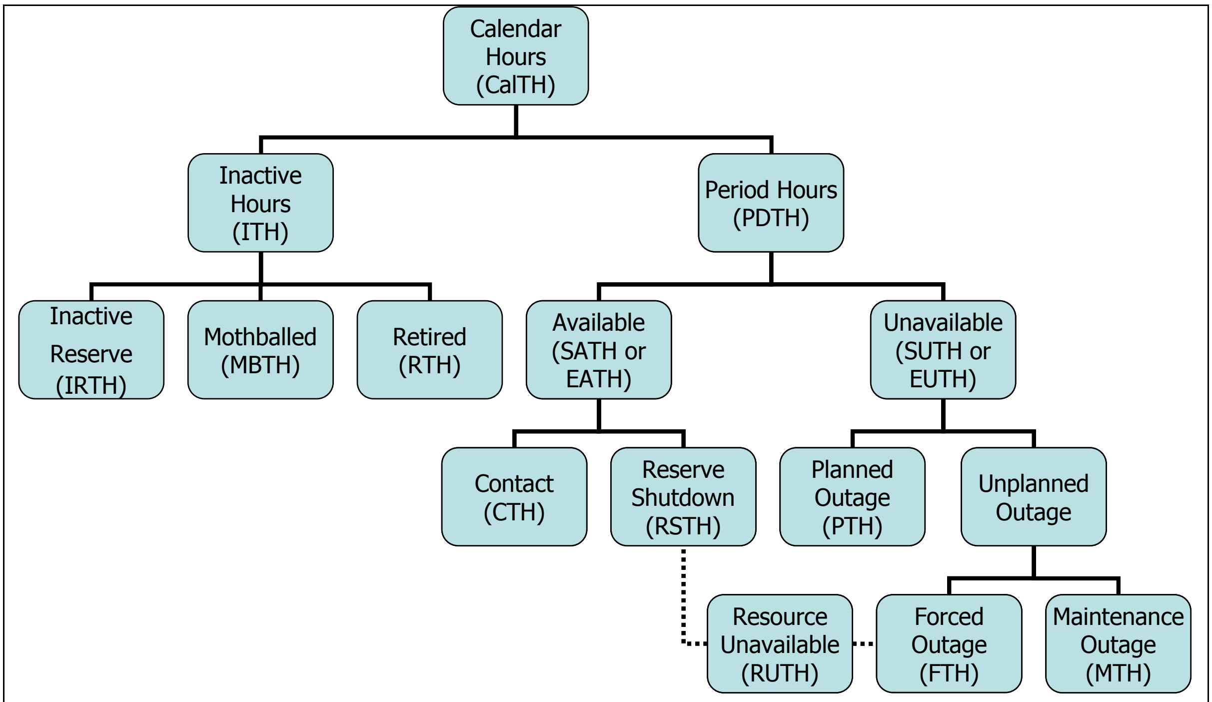


Figure 4. Units State flowchart

Turbine-Hours are equal to the number of turbines in the group or sub-group times the number of Calendar Hours in the period. TH for any given condition for a given sub-group is equal to the total number of Calendar Hours that each wind turbine (WTG) in the sub-group spent in the given condition.

Inactive Reserve Turbine-Hours – IRTH - Total number of turbine-hours for the period being reported that turbines within the sub-group are in the inactive reserve state.

Mothballed Turbine-Hours – MBTH - Total number of turbine-hours for the period being reported that turbines within the sub-group are in the mothballed state.

Retired Unit Turbine-Hours – RTH - Total number of turbine-hours for the period being reported that turbines within the sub-group are in the retired state.

Period Turbine-Hours – PDTH - the number of hours that turbines within the sub-group are in the active state. PDTH can vary in output reports (month, year, etc.) but for GADS reporting purposes, data is collected on the number of turbine-hours in a month.

Contact Turbine-Hours – CTH - the number of hours that turbines within the sub-group are synchronized to the system. It is the turbine-hours that the contactors are closed without regard to the grid connection.

Reserve Shutdown Turbine-Hours – RSTH - the sum of all hours that turbines within the sub-group are available to the system at a reduced capacity for economic reasons. There are no equipment problems and the turbines are ready for service. Do not include RSTH in the same equations with CTH because this would double count turbine-hours

Forced Turbine-Hours (FTH) - FTH is the sum of all the hours that turbines within the sub-group are off-line due to forced events. FTH are all forced events where the WTG must be removed from service for repairs *before* the next Sunday at 2400 (just before Sunday becomes Monday).

Maintenance Turbine-Hour (MTH) - MTH is the sum of all the hours that turbines within the sub-group are off-line due to a maintenance event.

Planned Turbine-Hour (PTH) - PTH is the sum of all the hours that turbines in the sub-group are off-line due to a planned event. A Planned Event is scheduled well in advance and is of predetermined duration and can occur several times a year.

Site Available Turbine-Hours (SATH) - SATH is the number of active turbine hours that the wind resource was available for generation. SATH is equal to the Period Turbine-Hours (PDTH) minus the sum of Planned Turbine-Hours (PTH), Forced Turbine-Hours (FTH), Maintenance Turbine-Hours (MTH) and Resource Unavailable Turbine-Hours (RUTH).

Equipment Available Turbine-Hours (EATH) - EATH is the total active turbine hours that the equipment is considered available for generation. It is equal to the sum of the Contact Turbine-Hours (CTH), Reserve Shutdown Turbine Hours and Resource Unavailable Turbine-Hours (RUTH).

Site Unavailable Turbine-Hours (SUTH) - SUTH is the total active turbine hours where the site was unavailable for generation due to equipment outages or unavailable resource. It is equal to the sum of Planned Turbine-Hours (PTH), Forced Turbine-Hours (FTH), Maintenance Turbine- Hours (MTH) and Resource Unavailable Turbine-Hours (RUTH).

Equipment Unavailable Turbine-Hours (EUTH) - EUTH is the total active turbine hours where the equipment was unavailable for generation due to equipment outages. It is equal to the sum of Planned Turbine-Hours (PTH), Forced Turbine-Hours (FTH), and Maintenance Turbine-Hours (MTH).

Resource Unavailable Turbine-Hours (RUTH). RUTH is the number of turbine-hours the turbines within a sub-group is not producing electricity due to the wind too low or too high or was outside manufacturer's operating specifications. For example, if 10 turbines stopped generating because of wind conditions for 3 hours each, RUTH would equal 30 turbine hours. RUTH is classified as Available Turbine-Hours for equipment calculations and Unavailable Turbine-Hours for site calculations.

Outside Management Control:

OMC Forced Turbine-Hours – oFTH - oFTH is a sub-set of FTH that equals any forced turbine-hours that were due to causes deemed to be outside of management control.

OMC Maintenance Turbine-Hour (oMTH) - oMTH is a sub-set of MTH that equals any maintenance Turbine-Hours that were due to causes deemed to be outside of management control (OMC). For more information on OMC, refer to *Appendix G*.

EQUATIONS FOR PERFORMANCE MEASURES

Resource and Equipment Calculations – These equations calculate the individual resource and equipment performance by turbine sub-group(s) that have the same, or very similar, capacities. These equations also include OMC hours.

Pooled Resource and Equipment Calculations – These equations pool the resource and equipment performance of sub-groups into collections of sub-groups, groups, or farms. These equations also include OMC hours.

Resource and Equipment Calculations without OMC Hours – These equations calculate the individual resource and equipment performance by turbine sub-group(s) that have the same, or very similar, capacities. These equations do not include OMC hours.

Multi-Resource and Multi-Equipment Calculations without OMC Hours – These equations pool the resource and equipment performance of sub-groups into collections of sub-groups, groups, or farms. These equations do not include OMC hours.

Resource Equivalent Forced Outage Factor (REFOF) –

% of period that the plant was forced off line. Including low and high winds.

$$REFOF = \frac{(FTH + RUTH)}{PDTH} \times 100$$

- Equipment Equivalent Forced Outage Factor (EEFOF)

  - *% of period that the WTG equipment was forced off line. Excluding low and high winds.*

$$EEFOF = \frac{FTH}{PDTH} \times 100$$

- Resource Equivalent Forced Outage Factor (REFOF)

% of period that the plant was forced off line. Including low and high winds.

$$REFOF = \frac{\sum (FTH + RUTH)}{\sum PDTH} \times 100$$

- Equipment Equivalent Forced Outage Factor (EEFOF)

% of period that the WTG equipment was forced off line.

$$EEFOF = \frac{\sum FTH}{\sum PDTH} \times 100$$

CONCLUSIONS AND FUTURE WORK

During the last years it has been proven the difficulty in building proper RES performance indicators databases. A lot of general RES databases have been found 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 first issue regarding RES performance indicators is the lack of normalized definition for the most important ones. Further detailed key performance indicators definitions are necessary (involving international organizations IEC/ISO).

The main conclusion is that RES business model is not comparable to conventional generation plants one because plant performance is not always “visible” to owners (Global service contracts with Manufacturers), there is a lack of business "maturity" in control-scada-data collection platforms for RES and KPI definition is not well standardized.

RES promoters are highly fragmented (small investors, land owners, banks, real state, utilities) and people are hesitant in providing operational information. New legal frameworks making data collection as mandatory are really needed.

RES technologies face some technical difficulties regarding data gathering. There are several generation units per plant (i.e. wind) so lots of data required for simple plant analysis and in many cases extreme condition locations lead to communication troubles and higher probability of lack of data.

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 report.

The future phases of RES WEC Work Group should re-define procedures focusing on standardization of data gathering and KPI calculation definition for RES, before dealing with databases creation, involving normalization agencies, manufacturers, technological associations, lobbies and RES consultants in addition to promoters.

Recent new projects like new NERC-GADS Wind database engaging promoters, institutions, wind associations… are the basis for future well done RES performance indicators databases.

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5. Technology Transfer : How to Make it Happen

Work Group 4
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INTRODUCTION

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. A significant contributor to maximising generating plant performance is to ensure that the plant technology is transferred in an effective manner between the technology owners and the plant recipients. 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

- a 25% improvement in technology and
- a 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 made 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 organisation 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.

At the environment external interface, a relationship has to be established between the technology supplier and the Government who should commit to supporting the technology to be transferred in ensuring that sustainable resource supplies will be available.

In support of this it is also important for the supplier to establish a long term business partnership with the technology recipient to advise and guide on the suitability of technology application and changes that may happen over time, this also allows the recipient to gain access to learning interventions directed to maximise the technology benefit.

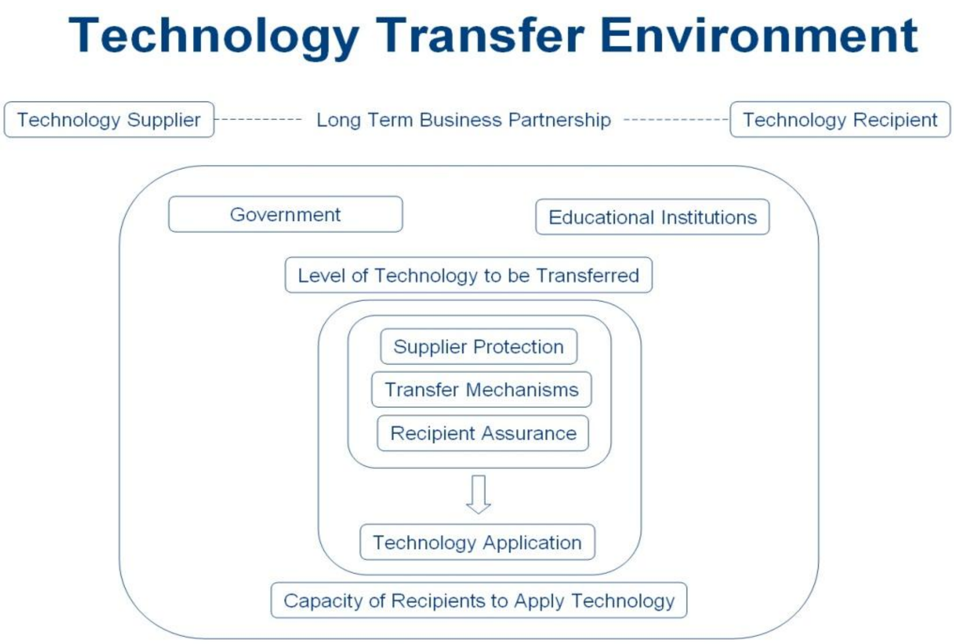

Figure 5-1

Government Involvement

Ideally, a strategy developed by the recipient country government should be in place to drive the adoption of technology and create the necessary legislature to ensure protection and support for the technology suppliers. This happened in South Korea where legislation was passed to ensure adequate Intellectual Property Rights protection. In addition the Government has taken decisive action against any perpetrators while mounting an information campaign to the public on the benefits of being given the opportunity to participate in Technology Transfer for the positive impact on South Korea's economic growth.

While it is important to nurture this support it should not be forgotten that Technology Transfer is a process which needs to be actively managed for its success.

Tax relief and dedicated land provisions to the technology providers were also arranged by the South Korean government to allow the providers to solely focus on the Technology Transfer. In some cases additional financial incentives can be offered for supplying higher grade technology.

Technology Transfer from the supplier can be increased by contracting more local content and developing local Research and Development. As in the case of the Argentine Nuclear Industry, host countries can support local firms with less performance demand on the OEMs. This can be in the form of education and training subsidies to the local firms. In addition increasing the number of external contractors can increase the competition, it is known that using only one main contractor can lower the industry's standard.

Technology Absorption Capacity

One of the challenges experienced in the Transfer is understanding how to cope with the different cultures between supplier and recipient.

Cases provided in the survey indicated that the process took much longer than anticipated. This highlights the need to understand the different precedents between the two parties. Use of a consultancy familiar with the recipient country would be advisable in enabling to compile the project timeline.

The complexity of technology to be transferred is dependent on the recipient country's ability to absorb the technology from both its implementation and its support through the academic institutions. These institutions can be challenged from a lack of scientific resources, a lack of scientific inquisitive nature leading to further research and a lack of management skills in pulling together the resources for the correct focus to the incoming technology. In these circumstances discussions with the recipient government should be considered to direct them to support the academic institutions. Failure to do this could result in the non-sustainability of the applied technology, due to the basic operating and maintenance practices not being provided.

Table 5-1

Some factors to consider in selecting the correct technology to be transferred:

Use of Advanced Technology

Benefits	Disadvantages
Critical to greater rate of economic growth	Can raise more problems than can be solved
Greatly accelerates the alleviation of underdevelopment	Very costly relative to income GDP
Gives the opportunity to enhance the overall institutional and organisational capacities for growth and change	Requires educational and industrial infrastructure that takes years to build
Cleaner, healthier and more efficient	Inhibits growth of indigenous innovation
Modern science and advanced technology are inextricably linked.	Weak technology bases and lack of research resources limit possibility of narrowing the technology gap

Challenges associated with Technology Transfer

Multinational companies carrying out large projects can invariably be effective in the Transfer of Technology but to ensure that it can be spread, with an improved chance of sustainability throughout the country, it has to be supported by utilising the existing infrastructural resources, known as the 'National System of Innovation', consisting of: productive, scientific and technological, management, education and training, financial and administrative regulatory systems. This network will enable generation, importation, assimilation, modification, diffusion and use of knowledge in the recipient country.

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 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

One type of Technology Transfer is known as 'spillover', this can occur as a result of the Technology Supplier increasing the degree of competition in the receiving country forcing inefficient local firms to invest in new equipment or staff.

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 are 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

Knowledge Transfer

In most cases the technology recipient is paying for the technology to be transferred and wants to get maximum value for the investment from a company as well as National perspective. The challenge lies is how to establish in the short term whether knowledge has been transferred.

Knowledge Management

Egbu (2000): Knowledge Management is the process by which knowledge is created, acquired, communicated, shared, applied and effectively utilised and managed in order to meet existing and emerging needs, to identify and exploit existing and acquired knowledge assets.

Knowledge consists of two components, namely explicit and tacit. Explicit knowledge is something that you can put your hands on, books, manuals, technical documents. Tacit knowledge is an inner knowledge owned by a person, gained through learning or experience and applied unconsciously like breathing.

Tacit knowledge cannot be transferred as simply as explicit, for example the handing over of technical manuals or documents. An effective method of transfer is to ensure close interaction between the supplier and receiving representatives but the difficulty lies in the lack of structure in identifying what will be transferred and how to ensure that the transfer has indeed effectively taken place. A method often adopted to ease transfer is to convert the tacit knowledge to explicit by documenting the tacit knowledge as a process flow with decision points enhanced by adding input from the Subject Matter Expert in relation to what is thought, said or felt at each step of the process.

Knowledge transfer is getting the right knowledge to the right people at the right time. It is about connection and not collection, a two way process of choice between individuals, specifically a human aspect, which can occur naturally and takes place in more formalised routines. A factor determining a company's competitive advantage is its ability to convert tacit knowledge into explicit knowledge through organisational learning. The following skills support the development of successful knowledge transfer:

Communication

This is a process by which people verbalise their feelings, express their opinions, convey their ideas, influence others and transmit knowledge. Gauging one's level of jargon and speed of delivery to the language fluency of the listener. Recognising the differing cultural meanings of verbal and non-verbal behaviour Listening and questioning to understand the views and opinions of others Awareness of what is expected at the initial stage of forging a relationship in order to build sufficient trust to work together productively

Behavioural expectations

- Awareness of behavior at meetings, including preparation and agenda management.
- Awareness of a style of leading, negotiating and breaking deadlocks.
- Recognition of how decisions are taken and the implication for time management.
- Knowing which cultural values are most likely to impact on business, e.g. leadership and decision-making style, importance of structure, individualistic compared to collectivist style of relationships and the importance of time
- Readiness to adapt to cultures whose values are different from one's own

Cross-culture team building

Learning networks are used to bring people together from different backgrounds to exchange practical ideas which may eventually result in innovative practices in companies. Because of the need for intimate human interaction between partners for the knowledge transfer, it is vital to develop team building between both the supplier and recipient teams.

A problem with business communication is that people cannot be forced to provide or accept knowledge. The environment that facilitates the release and exchange of information needs to support individuals and groups to assist information flow. Difficulties are imposed on short term one-off projects as it becomes problematic to establish the relationships necessary for all parties to share the same vision for the future resulting in reluctance to share knowledge between the parties.

Ten ways to embed knowledge management into organisational culture:

1. Reward knowledge sharing behaviour
2. Define and communicate knowledge management behaviour
3. Implement formal agreements on knowledge management for key positions
4. Make knowledge management company policy
5. Have managers systematically enforce and reinforce knowledge management
6. Identify knowledge management positions
7. Incentivise knowledge management actions
8. Explicitly manage knowledge management for each and every employee
9. Publicly recognize good knowledge management
10. Take action on poor knowledge management

Integrated dimensions should be considered to develop coherent knowledge management programs

Content

Define the knowledge that is strategically relevant to the organisation business needs as a first step in the implementation

People

Ensure that key personnel have access to the relevant know-how and that it is disseminated amongst the people in the business so that it can be applied to the benefit of the business

Culture

The captured knowledge must be in a form that can be readily understood and used within the business

Process

Knowledge management must not be a catch-all for all information available. Surveys should be conducted to ensure that the majority of knowledge required is acquired within the scope of the business requirements.

Infrastructure

The knowledge asset should be actively managed to ensure that it is regularly updated with appropriate access controls and process owners assigned. The knowledge should be accessible through existing centralised organisation systems so as to prevent ‘private’ data stores.

In order to ensure that Technology Transfer has been effectively executed, there should be an indication that Knowledge Transfer has happened and that this new knowledge is being applied consistently as a way of life to the business in a positive manner. The technology recipient has to be assured in a structured quantifiable manner that what is needed is being delivered.

Learning Effectiveness Measurement

One of the core elements of knowledge transfer is to ensure that effective learning has taken place utilising a process whereby before any learning intervention is carried out, Line Management draw up a User Requirement Specification indicating which competencies are desired and what is the expected business impact in applying these new competencies. The competencies and business impact are discussed with the learner to highlight the purpose and benefit of the learning intervention.

A method used in South Africa for most standardised learning methods is the use of the Unit Standard which specifies the learning curriculum and the expected outputs in the form of new skills.

The competencies to be acquired are not just the normal technical Knowledge, Skills and Attributes but include an effectiveness competency catalogue which is divided into banding throughout the organisation, e.g. Decision Making, Level 1 up to Advanced Decision Making. The model is known as the “3 Streams Plus”.

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

In order to expedite the process and reduce costs for unnecessary training, all learners are to be pre-assessed which will give a good profile when designing the course so that the same material is not required to be delivered more than once.

It is important to ensure separation of learning intervention curriculum and assessment design with that of the course design so that the learners are not taught to pass, but to acquire new competencies at the end of the intervention.

CASE STUDY

The technology transfer information collected from the survey of WEC PGP members appears in Table 3. From this information it was decided to develop one comprehensive case study of the Enel Maritza East 3 project in Bulgaria. A key element missing in the Enel case study is the measurement of Learning Effectiveness, an approach used by Eskom, which if included, provides a comprehensive model for use by WEC members going forward. The other survey contributions were analysed in terms of the Technology Transfer Environment model to identify alignment with best practice and the results are given in Appendix 1.

Supplier case study – Enel Maritza East 3 project:

Environment

Enel entered into discussions with the Bulgarian State discussing options that ensured the environment was established for technology transfer. In this case, it was a win-win situation as the Bulgarian State was agreeable to getting the power plant prepared to meet the stringent plant operating conditions for entry into the European Union.

The objective of the acquisition was to rehabilitate and transform the plant to meet the future energy needs of Bulgaria as a member of the European Union. This was a wise business choice as Bulgaria had no other EU Energy Policy compliant plants, which is still the current position.

Plenty of skilled Bulgarians available for the project had the capacity to absorb the technology and operate the plant into the future, together with adequate support from the local educational institutions. No action was needed on the part of Enel to develop capacity in this regard. The plant is fully compliant with the Bulgarian legal and regulatory framework, ensuring all relevant permits are in place with strict adherence to their requirements. (This was unusual as within the Bulgarian context, it is normally form over substance).

Fortunately the Maritza project started at a time when Bulgaria was starting on its path to European integration. By working closely with many Government agencies they were helped to turn the EU legislation into Bulgarian reality. The plant and operational processes also had to be transformed from an environmental perspective, in which the partnership played a major part in the definition and implementation of many practices related to environmental policy and compliance.

This indicates the need to ensure that the macro environment for technology transfer is pursued with vigour so as to lay a good foundation for success.

The partnership undertook a commitment to the Bulgarian Government to have equipment for the rehabilitation manufactured as far as possible by local Bulgarian companies. This commitment was enforced on the partnership by incorporating strict local content requirements in the Engineering, Procurement and Construction (EPC) contract.

Supplier protection

In 2003, the Maritza power plant was acquired from the state by a SPV (Special Purpose Vehicle, a legal entity used to facilitate the transfer of the power plant as a going concern when the plant is to be resold. Another benefit of using the SPV is limiting the financial risk to the parent companies, Enel and NGK, involved in the formation of the SPV).

In addition for sustainable technology transfer, it was important to ensure financial stability for the project; this was achieved by arranging for Non-Recourse Project Financing, a long term loan funded by the power plant. In order to mitigate the projects finances, hedging contracts were taken out to secure revenue streams from the power generation using power purchase agreements and gypsum contracts with the state mining enterprise. The input costs were similarly hedged with long term contracts for the supply of primary energy, limestone for desulphurisation and ash disposal.

This project was initiated as a Joint Venture partnership between Enel (73%) and the Bulgarian National Electricity Company, NEK (27%). NEK was 100% State Owned and were the previous owner of all state energy assets.

Funding of the project is on a 'Non-Recourse Project Finance Basis' in which the project funds itself from the projected cash flows. This is highly unusual in Eastern Europe and a first in Bulgaria. This posed risks in the project which had to be clearly understood so that they could be mitigated.

One of the major risks identified was that between the Power Purchase versus Primary Energy supply. This and other risks were addressed by forming several long term strategic partnerships between the Maritza power plant and identified contract partners which were integral to the entire project and its financing structure.

- Long term power purchase agreement (capacity and energy, Bulgarian NEK)
- Long term fuel supply agreement (MMI the state mining company)
- Long term ash disposal agreement (MMI the state mining company)
- Long term limestone (for gas desulphurization) supply agreements (two local companies)
- Long term gypsum (gas desulphurization by-product) sales agreement (Knauf, German gypsum product manufacturer)
- Engineering, Procurement and Construction (EPC) contract for the plant rehabilitation (Consortium of Enel and RWE)

The Maritza power plant rehabilitation contract was carried out on a Turnkey Agreement. No proprietary Enel technology was licensed within Bulgaria.

Technology Transfer Mechanism

Enel brought financing, expertise and technical know-how to transform the plant both technically and operationally to be in line with international best practice. NEK brought local market knowledge and local institutional support to the partnership.

Being a rehabilitation project, the supply of materials and equipment was split between the defined and variable scopes of work. The variable scope was only capable of being defined upon finalisation of detailed inspections of each unit during the rehabilitation process. Most of the local manufacturing was focused on fabrication and pre-fabrication of components required in the rehabilitation of the flue gas desulphurisation structures, boiler components and civil structures. Most of the new electrical equipment was sourced or manufactured locally.

In all cases, locally manufactured equipment was manufactured in accordance with specifications prepared either directly by the Maritza power plant and Enel engineering or by the Engineering, Procurement and Construction (EPC) consortium engineering group. A large Quality Assurance exercise was adopted within the manufacturing, delivery, acceptance and erection process to ensure quality and suitability of all deliveries.

Consultancy

Certain consulting activities within Bulgaria, such as grid system planning, constructional supervision, operational acceptance amongst others can only be carried out by state registered consultants. Knowledge transfer was not an issue in Bulgaria from a general technical perspective; the workforce was well educated and skilled. The successful project conducted by ENEL in Bulgaria on the power plant refurbishment did not have to consider these circumstances as there was an abundant supply of well-trained Bulgarians available to carry out the work.

An area where technology transfer was needed was in the local workforce becoming more efficient and understanding the concepts of project planning and meeting deadlines. This was effected by advising the local manufacturers of the machinery or processes to be used which were provided on a commercial basis as part of their contracts.

Recipient case study – Eskom

In Eskom's case there is a shortage of skilled persons 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.

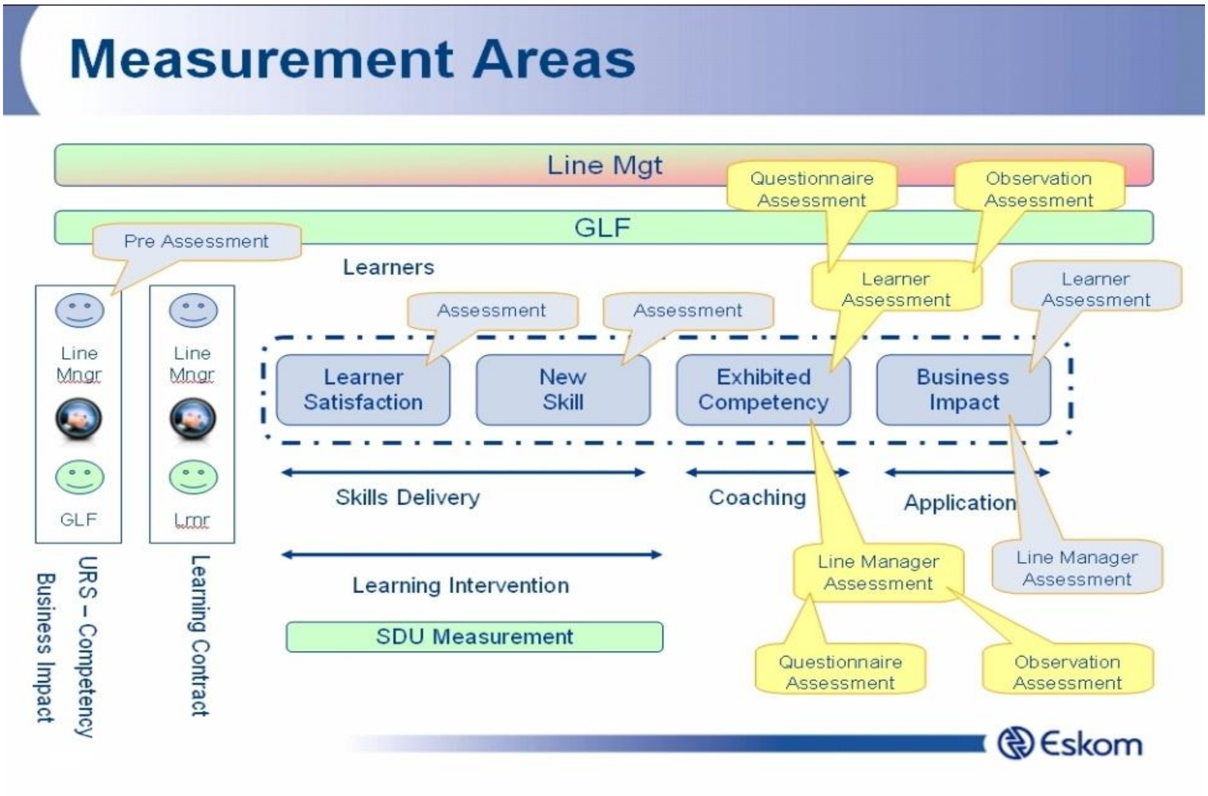

Figure 5-2

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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APPENDIX 1 – TECHNOLOGY TRANSFER WEC SURVEY COMPARISON

Environment

Cultural: Substantial delay to initial plan, build-up phase and implementation of process underestimated, ensure clarity between improvement and upgrade.

- Other technology partners imposing legal limitations on technology to transfer
- Export controls what technology can be exported from the supplier country
- Alstom, Anonymous
- Design and Manufacture transfer was not effective
- Mitshubishi, Japan
- Top level government decision to support the development of a nuclear industry
- Nucleoeléctrica Argentina SA
- Uncertain political environment
- Nucleoeléctrica Argentina SA
- Financial challenges

Supplier Protection

- IP concerns
- Legal support needed for agreements
- Alstom, Anonymous
- Joint Venture
- Anonymous, Nucleoeléctrica Argentina SA
- Turnkey
- CKD Blansko, Siemens AG
- Local suppliers failed due to environmental circumstances, Argentine industry had sufficient capacity to establish local supplier resource CNEA which also failed.
- Joint Venture failed due to financial challenges, Argentine industry had capacity to establish operation and maintenance unit for the country's existing nuclear power plants.
- Nucleoeléctrica Argentina SA
- Technology Transfer Mechanisms
- Access to OEMs product experience and knowledge
- Hand over JV Company to recipient
- Integrate and harmonize design tools from the start
- Alstom
- Training and qualification of manufacturing personnel addressed ahead of implementation
- Anonymous
- Initial supply of main equipment
- Philippine Bio Sciences Co Inc
- Training
- Philippine Bio Sciences Co Inc, Mitshubishi, Japan, CKD Blansko, IAEA, Eskom
- Field support in first year of operation
- OEM long term support
- Consider licensing local manufacture
- Mitshubishi, Japan
- Use of local suppliers
- Mitshubishi, Japan, Nucleoeléctrica Argentina SA
- Consultancy service (supply)
- IAEA
- Licensing Agreement
- Know-How Agreement
- Local manufacture
- Technology Transfer Agreement
- Nucleoeléctrica Argentina SA

- Consultancy service (receive)
- Shared staff between companies
- Nucleoeléctrica Argentina SA, Eskom
- Recipient Assurance
- Better training specifications needed in more detail
- Alstom, Eskom
- Identify pipeline learners to ensure sufficient capacity is available for development
- Ensure existing learners are made available for development and not involved in the day to day operations of the plant
- Develop required competency frameworks for each position from which learning interventions are created by drawing up curricula and course delivery methods. Assessments are compiled independently of the curricula and course designers to allow neutral evaluation of the extent of learning acquired by the learners.
- Eskom
- Application of Technology
- Mutual transfer of design technology implemented
- Alstom
- Gas turbine engineering and manufacturing project on track with good results
- Anonymous
- 10 years successful local manufacture of Circulating Fluidised Bed Combustion Boiler combustion chambers, USD 200 m pa turnover – recipient Poland
- EVT Stuttgart (GEC Alstom)
- Successful local manufacturing facilities established
- Competent in the operation of the equipment
- Export opportunities to Indonesia, Japan and Iran
- Use of existing swine waste for power generation results in electricity 26% cheaper
- Sustainable development
- Philippine Bio Sciences Co Inc
- Successful long term operation and maintenance of plant
- Mitshubishi, Japan, CKD Blansko
- 35 years successful plant operation
- Created sufficient capacity to start a new Nuclear power plant project, contract and negotiation
- Nucleoeléctrica Argentina SA
- Learners put in a position to: Design and project manage, Operate and maintain future new build plants
- Skills Capacity increased for the South African economy.
- Eskom

APPENDIX 2 –CONTRACTUAL AGREEMENTS

a. Intellectual Property Rights Sale

This is the sale by the owner of all its exclusive rights to say - proprietary technology and the corresponding purchase of these rights by another person or legal entity. If this transfer takes place without any condition imposed, time or otherwise, it is said that an 'assignment' of such rights has taken place.

b. Licensing

A "license" is granted when the owner of say a proprietary technology has given permission to another person to perform one or more of the "acts" which are covered by the exclusive rights to the proprietary technology within specified countries or country. These "acts" are the "making or using of an item which includes the technology, the making of products by a process that includes the technology or the use of the process that includes the technology". The license is usually granted subject to certain conditions as set out in the agreement. The licensee will relate one of the conditions to some consideration of money or services for the license to be granted. Other conditions may oblige the licensee to manufacture products for their own or a specific use, for example only to be used in the Generation industry, in specified factories or geographical areas.

In a number of countries, the patent law may require that the assignment of patent rights or a license contract be presented to the local patent office for registration. By the act of registration, the Government recognises the assignee or licensee as the holder of the rights transferred by the assignment or license.

c. Know-how Contract

A third legal method for the transfer and acquisition of technology concerns know-how. While it is possible that provisions for the transfer of know-how can be included in the License agreement it can be compiled as a separate document.

Know-how can be provided in both tangible and non-tangible forms.

Tangible Know-how ("technical data") can be supplied in a number of forms:

- Process Flow Charts
- Operating Manuals
- Material lists and specifications
- Stability and Environmental reports
- Job descriptions
- Plant drawings

Intangible Know-how

- Training of the recipient's staff in the supplier's works or the recipient's new installation.
- Explanation of processes by the suppliers engineer to the recipient staff witnessing a supplier's production line in operation.

A very real concern for the supplier is a strong possibility that the communicated Know-how is disclosed, accidentally or otherwise, to third parties. Provisions in the contract must include measures to safeguard against the disclosure to unauthorised persons.

d. Franchise

A business arrangement whereby the reputation, technical information and expertise of the supplier are combined with the investment of the recipient for the purpose of selling goods and / or services directly to the consumer. Marketing of such goods is based on a trademark or trade name. The licensing of such a distinguishing brand feature is normally combined with the supply of know-how covering a vast array of possibilities such as: technical information, technical services or management services concerning production, marketing, maintenance and administration.

e. Acquisition of Equipment

The commercial transfer and acquisition of technology can take place together with the purchase of the generating plant. Importing of equipment into the country for use by the recipient is in effect technology transfer. The Sale Contracts can be associated with a License Contract and / or a Know-how Contract in support of the recipient operating and maintaining the new equipment.

f. Consultancy Arrangements

Acquiring new plant assets may exceed the utilities existing skills capability requiring skills that are not available for building new plant. Consultants can be used in this case to assist in the planning for and actual acquisition of the given technology. The valuable knowledge acquired from the experience gained and lessons learned in engaging and working with the consultants can serve to better carry out future projects hence transferring technology.

g. Joint Venture Agreements

Two types of Joint Venture exist:

- Equity Joint Venture, in which two or more separate companies create a separate legal entity with funding contributions from all parties.
- Contractual Joint Venture. In certain circumstances the establishment of a separate legal entity is not needed or it is not possible to create, then the Contractual Joint Venture can achieve similar benefits.

Technology transfer takes place inside the Joint Venture using any of the identified legal agreement methods for transfer or acquisition of the new technology.

h. Turnkey Project

In certain instances, the business arrangements between the suppliers and recipients can be combined in such a way as to entrust the planning, construction and operation of a power plant to a single technology supplier or very limited number of technology suppliers. The "Turnkey" project may involve a comprehensive arrangement of contracts that require that the supplier hands over to the recipient an entire power plant that operates in accordance with agreed performance standards.

TABLE 3 – WEC SURVEY RESPONDENTS

Period	Information Provider Supplier / Recipient	Supplier	Why Transfer	What Contractual Arrangements	What is to be transferred	Plant / Equipment	Transfer Mechanisms	What is the objective of the transfer	Who are the stakeholders	Lessons Learned	Benefits	Outcome	Macro Factors, environmental, sustainable development	Recipient
1998 to 2009	S	Alstom			Manufacturing Servicing	Power Generation Electrical Eqpt	Training			Intellectual property concerns Substantial Delay to initial plan Traning requirements should have been specified in more detail Ensure clarity in definition between improvement and upgrade Legal support required for agreements	Access to OEM's product experience and knowledge OEM product support			Far East
1992 to 1995	S	Anonymous Europe		Joint Venture	Research & Development	Gas Turbine		Hand over JV company to recipient		Intellectual property concerns Uncertain political environment Other technology partners imposing legal limitations on technology transfer Export controls limit what technology can be exported Integrate and Harmonize design tools from the start		Mutual transfer of design technology		Russia

12. TABLE 3 – WEC SURVEY RESPONDENTS (cont)

Period	Information Provider Supplier / Recipient	Supplier	Why Transfer	What Contractual Arrangements	What is to be transferred	Plant / Equipment	Transfer Mechanisms	What is the objective of the transfer	Who are the stakeholders	Lessons Learned	Benefits	Outcome	Macro Factors, environmental, sustainable development	Recipient
2002 to 2005	S	Anonymous Europe		Joint Venture	Engineering Manufacturing	Gas Turbine				Intellectual property concerns Training and Qualification of manufacturing personnel addressed ahead of implementation Build-up phase and implementation of process underestimated Export controls limit what technology can be exported		Completed on track with good results		Developing Country
1990 to 2000	S	EVT Stuttgart (GEC Alstom) Germany			Manufacturing	(Circulating Fluidised Bed Combustion) Boiler - Combustion Chambers						Successful local manufacture for 10 years - USD 200 m annual turnover		Rafako, Poland
2007	R	Philippine Bio Sciences Co Inc			Manufacturing Install Operate	Biogas production for power generation	Training Initial supply of main equipment			Export opportunities to Indonesia, Japan and Iran	Electricity 26 % cheaper	Local manufacturing and operation of equipment	Use of existing swine waste for power generation - sustainable development	Empire Farms, Philippines / Tarlac

12. TABLE 3 – WEC SURVEY RESPONDENTS (cont)

Period	Information Provider Supplier / Recipient	Supplier	Why Transfer	What Contractual Arrangements	What is to be transferred	Plant / Equipment	Transfer Mechanisms	What is the objective of the transfer	Who are the stakeholders	Lessons Learned	Benefits	Outcome	Macro Factors, environmental, sustainable development	Recipient
1978 to 1983	S	Mitshubishi Japan			Operate Maintain Construction	Geothermal power plant Geothermal power plant Civil and pipework	Training Field support in first year of operation OEM support			Consider licensing local manufacture Design and Manufacture transfer not effective Benefit of using local suppliers for the civil construction and pipework		Successful 25 year operation and maintainance of plant		Kamojang GPP Indonesia
2008	S	CKD Blansko, Czech Republic		Turnkey	Operate Maintain	Wind Turbines Small Hydro	Training					Successful operation and maintenance of plant		Various
Ongoing	S	IAEA		Consultancy	Design Operate Maintain Policy decision	Nuclear Power Plant Nuclear Power Plant Infrastructure	Training Consultancy					Support to all potential and current Nuclear plant operators		

12. TABLE 3 – WEC SURVEY RESPONDENTS (cont)

Period	Information Provider Supplier / Recipient	Supplier	Why Transfer	What Contractual Arrangements	What is to be transferred	Plant / Equipment	Transfer Mechanisms	What is the objective of the transfer	Who are the stakeholders	Lessons Learned	Benefits	Outcome	Macro Factors, environmental, sustainable development	Recipient
Ongoing	R	Various		Equipment Contracts	Design Operate Maintain Construction Project Management	Thermal power plant	Training Consultancy Shared Staff			Detailed Training requirements required Ensure pipelining of staff for knowledge transfer Ensure staff are available for training Ensure proper measurement systems are in place Capture competency developments in organisation data stores linked to staff records		Staff able to project manage future power plants Staff able to operate and maintain new build and future power plants Skills capacity increased for the South African economy		Eskom
	S	ENEL										Refurbished and upgraded power plant in successful operation Local manufacturing industry established		Bulgaria
1968 to 1974	R	Siemens AG	Establish Nuclear industry	Turnkey Licensing Know How	Manufacture Engineering Assembly	Nuclear power plant		Build capacity in Nuclear Industry, Construction and Operation Utility and local manufacture - 12 % of total purchase orders	Top level government decision		Created sufficient capacity to start a new NPP project, contract and negotiation	35 years successful plant operation		Nucleoeléctrica Argentina SA

TABLE 3 – WEC SURVEY RESPONDENTS (cont)

Period	Information Provider Supplier / Recipient	Supplier	Why Transfer	What Contractual Arrangements	What is to be transferred	Plant / Equipment	Transfer Mechanisms	What is the objective of the transfer	Who are the stakeholders	Lessons Learned	Benefits	Outcome	Macro Factors, environmental, sustainable development	Recipient
1973 to 1984	R	Atomic Energy of Canada ltd Italipianti SA	Further develop Nuclear industry	Technology Transfer Know How Consultancy	Construction design Plant Operations Assignment of Argentinian construction rights R&D Engineering	Nuclear power plant		Build capacity in Nuclear Industry, Construction and Operation Utility and local manufacture		Political challenges Financial challenges AECL failed to be local supplier Ability to swap AECL as local suppliers to CNEA CNEA failed to be local supplier of choice		Successful NPP operation Successful Technology Transfer		Nucleoeléctrica Argentina SA
1979 to present	R	Siemens AG	Build 4 NPP and further develop nuclear industry	Joint Venture Know How Technology Transfer	Power plant construction Business Management System design Component design Construction Commissioning Project Management Operation Maintenance	Nuclear power plant				OEM pulled out, no longer in the nuclear business Joint Venture failed due to budget constraints Joint venture changed from full NPP industry to operate and maintain existing plant		One NPP completed and in operation		Nucleoeléctrica Argentina SA

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