Performance of Generating Plant: New Realities, New Needs

1. INTRODUCTION

The availability of a power plant is a critical indicator for assessing the overall performance of the plant and its service to customers. For over 30 years the WEC Committee on the Performance of Generating Plant (PGP) has compiled and published performance data of power generating plants worldwide and produced regular reports containing examples of advanced techniques and methods for improving power plant performance through benchmarking.

> Analysis of power plant performance data compiled by the Committee has shown a substantial gap between the worldwide average performance and that being achieved by top performing plants. It has been estimated that eliminating that gap would result in savings of US$80 billion per year. Since the existing plants could operate with higher availability, there would be no need to design, finance, build and operate additional capacity. Moreover, this improvement in performance would reduce GHG emissions by 1 billion tonnes CO_2 (approximately 4% of the total global emissions) per year, along with proportional reduction of other pollutants. This could be implemented at an average benefit to cost ratio of 4:1. Case studies compiled by the PGP Committee members from utilities and companies around the world have indicated that while some technology enhancements and equipment upgrades will be required, the majority of the improvement will come as a result of addressing human factor issues and power plant management. In fact, if these areas are not improved, new technology plants will be unable to achieve their inherent superior performance potential.

In a regulated environment, plant performance was largely measured on the ability to deliver the required load (i.e., the obligation of supply), and on the effectiveness of covering the cost of supply. Traditional indicators were used to measure availability, such as planned outage rates, and unplanned or forced outage rates.

2. NEW OPERATING ENVIRONMENT REQUIRES NEW SOLUTIONS

In recent years the need to develop and use new reliability indices, which more accurately reflect the current market place, has taken on a high degree of urgency. It is brought on by the need of large power consumers for lower electricity prices in order to compete in the global economy. To meet this need, electricity generators are being compelled to reduce their costs. Decision-making at all levels is being affected and the old "technical" definitions of reliability are being amended to incorporate economics in order to link in a better way plant performance with the actual cost of electricity supply. Rather than applying traditional measures that are calculated over both demand and non-demand periods, new reliability terms are considering only the hours that the plant would have been dispatched and the financial consequences to the company's bottom line from the failure to generate during those hours.

An examination of recent industry trends, actions, and reactions at a higher level, leads to several conclusions:

- Capital remains at a premium;
- Fuel selection, energy efficiency and environmental requirements are becoming increasingly interlinked;
- In most electricity markets, there are commercial entities focused on delivering profits to their shareholders.

This creates new expectations and pressures, and even traditional power producers, whether owned by governments or private regulated integrated utilities feel the need to:

- Address performance within a financial context;
- Manage operational risk; and
- Address environmental/political pressures.

As the issue of generating plant performance evaluation becomes increasingly complex, the ability to “measure” and analyse this performance is getting even more challenging. There is no clear “right” answer on how to address this issue; different entities, different facilities, different markets, and different obligations will yield different needs. It should not be surprising, therefore, that the electricity supply industry seems to be at a crossroad, both in terms of how it measures its performance, and also in terms of data or information necessary to support such measurements.

Commercial Availability

The term Commercial Availability (CA) emerged in the United Kingdom in the early 1990's following the deregulation of the UK power industry and the introduction of a "market" system. Since a plant's availability only had value to its owner, if it could generate power at a profit, it was only measured during the times the market price was above the plant's variable cost. Initially, CA was not “weighted” and it was assumed that each hour that the unit was economically viable had the same influence on CA.

Over time, some users of CA have developed the definition to include the influence of the price/cost gap magnitude which produced a more accurate indicator of the plant's impact on the company's profitability. For example, during hours when the gap is US$20/MWh, the plant's actual availability would have ten times greater influence on the profits than an hour in which the gap was only US$2/MWh.

Therefore, CA attempts to measure the ***actual profit*** delivered by the plant relative to the ***potential profit***, had the plant been able to deliver every MWh required of it at the actual market price. (Profit here is defined as gross margin, i.e., generally the difference between the plant's variable production cost and the market price, or the system's marginal cost in the case of regulated companies). Different equations for CA have been independently developed attempting to measure the financial impact of a unit's unavailability. Some of these are described in the report.

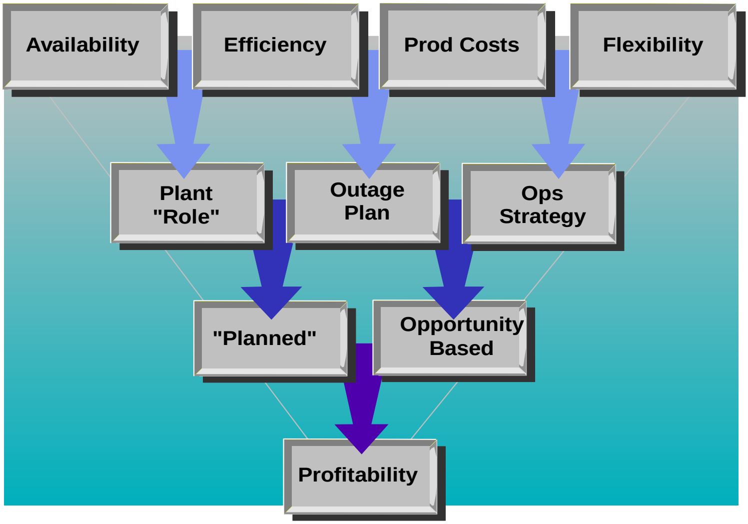
In some cases, profitability or business "success" is now a function of operations within a dynamic environment – an environment that can cause the "role" of the plant to be "redefined" from base-load to mid-tier, to peaking at different times of year; an environment where the "value" of each MWh can shift by a factor of 10 or even a 100 in a very short period of time; and an environment with many complex, often conflicting economic, technical, and environmental objectives.

This means that the ***core*** performance elements (availability, efficiency, production costs, and unit flexibility) must be tightly coupled to business objectives. Analysis and decision-making frameworks must, in turn, be geared toward overall goals and/or specific sources of opportunity presented in the market.

This environment is driving the industry to "redefine" its performance, to shift from the traditional technical perspectives to the more global view of efficiently managing all key processes (access to finance, fuels, maintenance, outages, heat rate, etc.). Obviously, "profits" in reality are a far more complex objective function that could include:

- Profitability/cost management;
- Obligation of supply;
- Environmental compliance (under current and future regulatory frameworks);
- Maximisation of return on capital investment;

- Optimal strategy for retirement/replacement of generation facilities to address aging, safety, environmental, fuel, or other techno-economic factors.



Benchmarking

Over the past few decades benchmarking has become a key tool in most top performing generating companies for performance improvement efforts. A recommended approach is first to identify other “peer” plants whose design and operational characteristics are similar to the unit in question. The WEC has used this advanced statistical technique, simultaneously analysing over 50 plant features, to identify peer units from different parts of the world and then to compare their “traditional” reliability indices. Benchmarking commercial availability will require a new aspect of the plant to be included in the analysis to determine the optimal peer group. That new aspect is an indicator of the plant's economic performance.

3. PGP DATA COLLECTION AND ANALYSIS

During the last 12 years, the PGP Committee has been examining the compatibility of international technical databases, demonstrating the value of benchmarking, and, more recently, has investigated the needs for further development of such systems to address the new, more competitive global power industry. The Committee has found that while data currently available continues to be of great importance and has high analytical value, there is greater potential and value in more in-depth, comprehensive data collection.

The Committee is cooperating with a number of leading organisations throughout the world that collect generating plant data:

- EURELECTRIC
- IAEA – International Atomic Energy Agency
- NERC – North American Electric Reliability Council.

Traditionally, statistics collected and evaluated at the international level have been aggregated by country and, hence, lack specific but valuable details:

- Size, age, fuel type, major equipment configuration/ manufacturers, etc.;
- System or component level failure, outage, and other maintenance detail;
- Linking lost availability to a standard “degree” or measure of need of the unit.

In many cases, the aggregation of data is a reality imposed by the lack of tools and/or processes to capture, validate, and collect/report data at a lower level. In other cases, companies used the aggregated reporting format as a means for “protecting” the data. The result was that, limited by such conventional and limited sources of data, many organisations have not been able to track and analyse performance and reliability of power plants according to design, operations, or age criteria. Without such data, it is not possible to divide power plants into statistically valid peer groups.

Paradoxically, at the same time as the reporting to databases has either declined or remained constant, the interest within the industry in having access to and applying such data is growing substantially due to the following:

- Failures in system reliability, including large-scale blackouts have demonstrated the need for system reliability;
- The excitement of the "market" to provide incentives/ mechanisms required to create liquidity and reliable supply of power has been faced with the reality of insufficient transmission capability, and the realisation that the physical asset (vs. financial market instruments) is fundamental to improving industry performance;
- Lack of capital, limited maintenance due to uncertainty about continued plant viability, growing environmental and regulatory pressures, and industry transformations have left many plants in sub-optimal conditions;
- There is a critical need to be able to place available capital toward areas of greatest need AND identify non-capital intensive performance improvement solutions;
- Irrespective of actual form of the market, its sheer presence will dictate the need for operational strategies, processes, and measures that address the actual business realities;
- Transparency in market operation and the ability to measure/benchmark performance relative to other industry players is a key strategy for generators to improve their performance;
- Market dynamics and financial implications on performance make the problem of data collection and analysis much more challenging.

WEC's Goal: A Global Data Collection and Analysis System

During the last few years, it has become clear that a "new" solution for collecting, managing, analysing, and reporting performance data and statistics is needed. It has also become clear that the best opportunity for success will lie in the ability to identify a solution independent of commercial pressures and capable of evolving over time. Moreover, the system would need to take into account a wide range of issues for both developing and developed countries. The WEC PGP Committee has taken the lead and begun the development of a new global power plant performance data collection/reporting system.

The goal is to create a worldwide data collection/reporting system to measure the performance of power plant components, equipment and technologies. The system is being designed to work in conjunction with other existing systems: NERC GADS, Eurelectric/VGB, and PRIS. It will be flexible and will allow continued evolution of its capabilities over time and the ability to interface with other existing data collection systems. A working model of the data collection and reporting process is being tested.

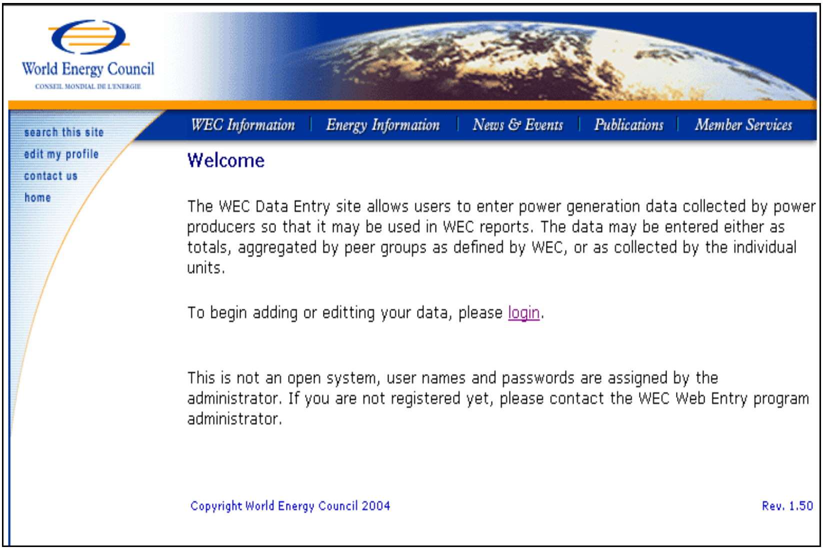
Governing Design Principles

Integrating commercial aspects of performance into measures, practices, and data collection system is quite complicated due to:

1. Wide variations in market structures around the world;
2. Differences in "how" profitability can be achieved within these markets due to differences in forms of contracts, management of power plants portfolios, and a degree of excess capacity in the market;
3. Need to be able to "benchmark" results without access to confidential price/cost data.

The ability to address the overall performance and availability "equation" is the principal driver in the system design. The WEC Performance of Generating Plant Committee is introducing the first phase of the Internet-based easy method for collecting data on electric power plants worldwide. The database is currently open to WEC Members only.

The system is offering several options for data collection and reporting. The reporting country can report data for groups of units or provide unit-specific data. The unit-specific data option is recommended but not mandatory.



The fundamental objective of a nuclear power plant is to generate electricity in an economic, safe and reliable manner. A plant is performing well when it fulfils this objective under overall satisfactory conditions. There is no simple way to measure overall plant performance, nor is there a single indicator which could be used for this purpose, because the conditions of economic competitive safety and reliability must be fulfilled simultaneously and each has its own particular aspects to be taken into account.

4. THERMAL GENERATING PLANT

A fairly large amount of statistical information has been left behind during the transfer of data collection onto a new system, as the data format was not directly compatible.

As the database grows, it is expected to become a unique global reference source for availability factor expectations, particularly useful for countries in the early stages of employing gas turbine plant and combined cycle plant as part of their power systems.

The most complete information in the database is currently available for major countries, such as Canada, Japan, and the United States, and some Western European countries.

Canada

Canada provided the 2002 data for 23 base-loaded fossil units, representing 8,890 MW, whereof thirteen units are in the 400-599 MW range. It appears that during the last reporting period (2000-2002) there were an unusually high number of external problems. The average PUF was 11.8%, which is 3.4% higher than the world average (8.4%). The UUF was 13.1% or 5.3% higher than the world average (7.8%).

The 400-599 MW units reported an EAF of 78.46% EAF, with very few external problems (UCF = 78.49%). However, this group of units also had a few problems. Almost twice as many outages for this group were unplanned rather than planned events (14.0% UUF and 7.5% PUF).

The Canadian Electricity Association (CEA) and NERC GADS are forming a union where the data collected by CEA will be converted into NERC GADS format. From there, GADS will supply unit-specific data to the WEC PGP database just as it does for the United States.

United States

The NERC GADS database has shown an increase in participation in the last several years. The reason for more participation in GADS is due to a ruling by the NERC Planning Committee (one of three NERC standing committees) in November 2000. At that time, the NERC PC modified the GADS Data Release Guidelines to state that if a power generator did not report data to GADS, then they would not have access to the GADS software product pc-GAR, developed especially for use in analysing all North American power plants by design, statistics, or performance parameters. Using this software, users can benchmark units, determine peers, examine manufacturer performance, determine the expected performance of units in future years, and many more things. As a result of the Guideline changes, GADS received event and performance records for 4,102 units (648,300 MW) in 2003. This is the highest number of units reported to GADS in its 22-year history.

During the 2000-2002 survey period, the United States provided data for 795 base-loaded fossil, 45 combined cycle, and 384 hydro units. The average capacity of the 795 fossil units was 300,463 MW of which 687 units (or 86%) were coal-fired. This 86% represents 246,547 MW of installed capacity. The combined cycle units represent 10,553 MW and the hydro units represent 48,130 MW of installed capacity, respectively.

Summary of US units

2000-2002 Average	EAF	PUF	UUF
Fossil, All Fossil Fuels	84.0	8.3	7.7
Fossil, Solid Fossil Fuels	84.4	8.1	7.5
Combined Cycle	87.0	8.2	4.8
Hydro	81.0	16.7	2.3
All US Base-loaded Units	83.8	7.0	9.2

The average EAF for US plants is the same as in the 1997-1999 survey (about 83%), as is the sum of unplanned and planned outages. However, this table shows that unit outages for US fossil units are just about evenly distributed between unplanned and planned events, with planned having a slight advantage. This is a decrease in planning of outages from the last survey. In the 1997-1999 survey, the US units had twice as many planned outage events as unplanned, similar to the statistics for the combined cycle PUF/UUF ratio above.

This increase in the number of unplanned outages for fossil units could be the results of several reasons, including units not being allowed to have outages due to demand of power, and older units having to operate more, resulting in more unplanned events.

More and more US companies are joining Independent System Operators (ISO) and are under more strict demand for power. ISO organisations require the cheapest (cost/MW) units to operate first before other, more costly units are dispatched. Sometimes there is no permission to take units off line for repairs until it is more convenient to do so. That may take a week or more after the problems are discovered and reported. If a unit needs repairs, prolonged operation results in more damage to the equipment and longer repair times.

The solid fuel (coal) units performed slightly better than the liquid and gas units. It is suspected that the coal units are repaired more quickly because they are the main source of electric energy in the US.

A large number of combined cycle units have been installed in the US. About 95% of all new construction in the US is by IPP and the majority are combined cycle designs. The large majority of the units are natural gas fired. However, in a few cases, the demand for natural gas has put some combined cycle units outside the “low cost” range set by the ISO. The resulting action is to increase operation of coal units (economics).

Europe

Due to the introduction of a new reporting format, the data for Europe is not directly comparable with the previous surveys. Nevertheless, the average EAF calculated for European plants demonstrates an improving trend.

Summary of European Units
(All Fossil Fuels, Fossil Steam Units, 100 MW or Larger)
EAF 2000-2002

	2000	2001	2002	Average
100 to 199 MW	89.45	85.77	83.43	86.22
200 to 299 MW	86.37	90.68	80.40	85.82
300 to 399 MW	87.66	91.18	86.03	88.29
400 to 599 MW	88.93	85.00	76.61	83.51
600 to 799 MW	86.03	94.5	62.10	80.88

Japan

Japan provided an extensive set of data for the 2000-2002 survey. The available information shows clearly the specific characteristics of operational experience in Japan.

The set of Japanese base-load fossil-fuel plants represented 148 units and 84,700 MW in the period 2000-2002. The average EAF of these plants is 83.6% (82.9% for the previous survey in 1997-1999), while PUF equals 15.1% (16.2% previously) and UUF, 1.3% (0.9 % previously).

Although the global average result for energy availability factor is in the same order of magnitude as the world average (83.8 %), the balance between PUF and UUF is completely different. The Japanese operators demonstrate a wonderful example of planning outages and making repairs correctly so that there are few unplanned outages.

The fact that the PUF factor for Japan moved from 18.7 % in 1994 to 14.7% in 2002 shows very clearly that a very cautious, but positive policy, has been implemented to achieve better operating optimisation in these units. As base-load units, they must operate to the maximum (optimum) of their capabilities, therefore, it seems that the extension of such a careful policy, facing a more demanding market, could reveal additional availability improvements.

5. NUCLEAR POWER PLANT INFORMATION

Information and data on nuclear power reactors have been collected by the IAEA since its establishment. The Power Reactor Information System (PRIS) developed and used by the IAEA includes two types of data: general and design information on power reactors, and data on operating experience of nuclear power plants. General and design information covers data on all reactors in the world that are in operation, under construction, or shutdown. Operating experience data covers operating reactors and historical data on shutdown reactors since the beginning of their commercial operation.

PRIS contains the largest amount of worldwide statistical information on operating experience. Although there are other data banks, the IAEA PRIS is considered the most complete and authoritative source of statistical data on the subject area. It makes it easy to identify individual units with their main characteristics, and to determine nuclear power development status and trends worldwide, in regions or in individual countries.

Since 1990, the IAEA has compiled information, available but spread over a large number of documents, on additional technical characteristics, covering items related to the mode of plant operation, safety characteristics, features and analysis report and of emergency plans, plant environment, etc.

Current Status of Nuclear Power Worldwide

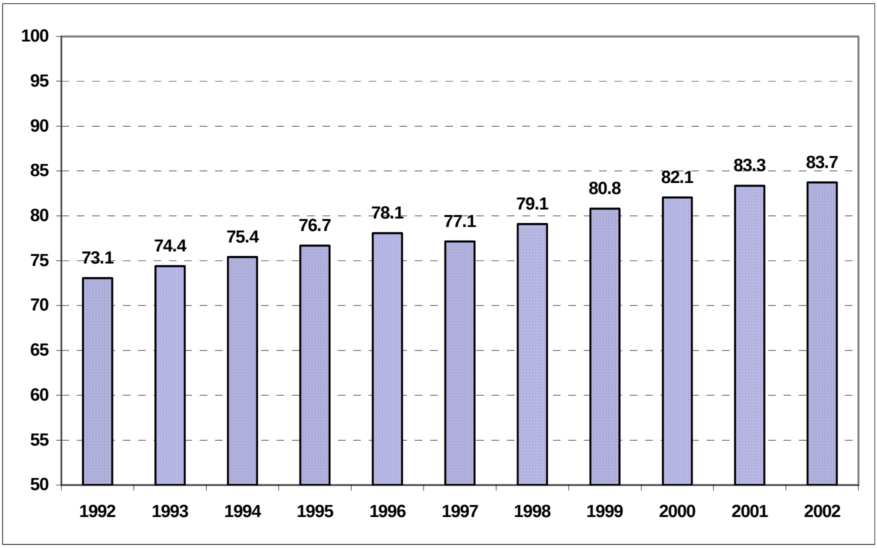
A total of 439 nuclear power plants were operating around the world at the end of 2003, according to data reported to the IAEA's Power Reactor Information System. The plants had a total net installed capacity of 361 GW(e). Also during 2003, two nuclear power plants representing 1625 MW(e) net electric capacity were connected to the grid, one in China, and the second one in Korea.

Additionally, construction of one new nuclear reactor in India started in 2003, bringing the total number of nuclear reactors reported as being under construction to 31, out of which 18 are located in Asia, where both population and economic growth are high, as is per capita energy consumption. Worldwide in 2003, total nuclear generated electricity increased to 2524.03 TWh. Cumulative worldwide operating experience from civil nuclear power reactors at the end of 2003 exceeded 11,143 reactor-years.

China is the most recent developing country to adopt nuclear power. It is currently operating 9 units and will have 17 units by 2010. India currently operates 14 Nuclear Power Plants (NPPs) and is constructing 8 more units, including the Fast Breeder Test Reactor. In Europe, the Finnish utility TVO has decided to build a 5th reactor on the existing Olkiluoto site. It is a 1600MWe EPR from a French German consortium.

Worldwide Results

There has been a steady improvement in the World Energy Availability Factor as shown in the figure below. The EAF grew from about 73% in 1992 to 83.3% in 2001, and achieved 83.7% in 2002.



World Energy Availability Factors for Nuclear Power Plants

The number of plants demonstrating higher energy availability factors (greater than 75%) has also increased. In 2002, 51 out of 439 operating nuclear power plants presented an energy availability factor between 70% and 79% and 328 plants presented an EAF higher than 80%. The cumulative world energy availability factor since the beginning of commercial operation and up to 2002 for non-prototype reactors is 76.1%, while the planned energy unavailability factor (PUF) is 16%.

There has been a steady decrease in both planned and unplanned energy unavailability factors over the last years indicating continuing improvement in plant maintenance management. The average planned energy unavailability factor decreased continuously from about 16.1% in the period 1993-1995 to 14.5% in 1996-1998 and achieved 12% in 1999-2001.

Nuclear plant operators are achieving high availability through integrated programmes, where international cooperation is playing a key role. The IAEA activities, which include nuclear power plant performance assessment and feedback, outage optimisation and effective quality management, are important examples of international cooperation to improve the performance of operating nuclear power plants. The World Association of Nuclear Operators (WANO) also plays a role in maximising the safety and reliability of the operation of nuclear plants, by exchanging information and encouraging experience sharing.

6. RENEWABLE ENERGY

Hydro and Pump Storage Plant

Hydropower is the world's largest source of renewable energy used for power generation; it accounts for 17% of the world's electricity production. Hydro resources are widely spread and used around the world, and more than 150 countries use hydropower for electricity generation. The main remaining hydropower potential development exists in developing countries in Asia, South America and Africa. For example, Europe has developed 75% of its economic hydro potential, while Africa only about 7%.

Storage of electric power is one of the major challenges facing further development of many environmentally sound renewable energy technologies. Hydropower storage schemes, such as pumped storage, are uniquely efficient and suitable to support many intermittent renewable technologies. Given its versatile range of applications, hydropower is widely used to provide grid stability and essential ancillary services, e.g. black start-up, frequency control and flexible reactive loading.

In the majority of power systems, the short-term power demand can reach 200% of the system average value. Hydro storage plants can be deployed at short notice to cover the peak demand, and this gives the plant operator a considerable competitive advantage. In a market environment, electricity prices can change both significantly and quickly during the day. Hydro peaking plants offer a unique flexibility, which enables utilities to follow and quickly respond to changes in demand.

Since 2002, the PGP Committee has had a Work Group on the Performance of Hydro & Pump Storage Plant. The objective of this group is to collect and provide data for the PGP database and the triennial report on the Performance of Generating Plant. This turned out to be a significant challenge, as the collection of data amongst the "hydro fraternity" is in no way as prevalent as within thermal and nuclear "communities". The new WEC PGP database is expected to facilitate the task of both recording and benchmarking of Hydro & Pump Storage Plant performance.

Other Renewable Energies

The share of renewable energy in power generation is growing rapidly, albeit from a very low basis. Due to the specific characteristics and widely perceived advantages of renewable energy, especially in terms of "sustainable development", it has become necessary to develop a separate set of performance indicators for renewable power plant. WEC has taken the lead and produced a proposal for a set of indicators. Economical indicators have not been included at this stage of the work, because it is a huge task taking into account the variety of circumstances around the world, the rapid development of Renewable Energy Sources (RES) and issues of "confidentiality".

However some general economical indications, figures and comments are presented in the report in order to give a more complete overview of the issues facing RES.

In order to understand the development of renewable energy, it is essential to consider the existing pattern of electricity demand. Today, roughly one third of the world population (about two billion people) do not have access to electricity. Another billion people have less than five hours of electricity per day. Moreover, the gap between industrial and developing countries is increasing dramatically. Many studies project that in the next two decades, the global demand for electricity will increase by more than 50% (world average), and developing countries will account for 90% of this growth.

At the same time, environmental concerns (above all, the increasing concentration of greenhouse gases in the atmosphere) require drastic changes in the behaviour of both developed and developing countries to ensure a transition towards "sustainable development", which in particular includes the development of renewable energy.

Source	Electricity production in 2002 (TWh)	Share in 2002	Average annual growth 1993–2002	Annual growth 2001–2002
Fossil	10 484.00	65.00%	3.4%	3.3%
Nuclear	2 720.00	16.90%	2.4%	2.1%
Hydro (incl. Pump storage)	2 643.00	16.40%	1.0%	1.8%
Biomass	175.10	1.10%	4.9%	3.2%
Geothermal	49.30	0.31%	2.5%	1.2%
Wind	53.60	0.33%	29.2%	35.1%
Solar	1.95	0.01%	13.5%	20.1%

Source: IEA/OECD Statistics, 2002

7. CASE STUDIES

The main objective of the PGP Committee's Work Group 7 is to develop Committee's communication activities to ensure the wide international dissemination of results of the Committee's work. This includes organisation of workshops and other events to present and discuss the numerous useful concepts developed by the Committee and to promote their wide application by the global electric power sector. It also aims to develop the use of IT and the Internet for communication purposes, including the introduction of the "Case Study of the Month" initiative on the WEC's Global Energy Information System at http://www.worldenergy.org.

The WEC Committee on the Performance of Generating Plant was established 30 years ago to enable the countries and electricity producers to evaluate the performance of the plants, detect their weaknesses, and gain experience from their successful performance improvement efforts of other producers. The value of international power plant availability data exchange is even higher today than it was three decades ago.

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