

**World\***

Figure 4-3 shows the value of EAF (%) as diagonals in the graph background, since  $EAF = 100 - (PUF + UUF)$ . Given this overall presentation, it is easier to determine the general trend for EAF and the respective roles of PUF (planned) and UUF (unplanned and other) in this change. In other terms, assuming that the volume of maintenance can be represented approximately by the level PUF, the level UUF approximately can represent the "quality" of this maintenance (maintenance perfectly adapted - no unplanned outages or unavailability, resulting in  $UUF = 0\%$ ).

The distribution for PUF and UUF for the World\* sample is given in the Figure 4-3, for the four periods 1997-1999, 1994-1996 (Houston Congress), 1991-1993 (Tokyo Congress), and 1986-1990 (Madrid Congress).

As regards the averages observed over the last three-year period (1997-1999), the most obvious conclusions from the steam turbines statistics (tables in Appendices C1 to C15) are as follows:

- The average energy availability factor (worldwide, all unit sizes, all fuel types) totalled 83.5% (1830 units, 600,000 MW), as compared to 82.3 % average for the 1994-1996. Depending on the size, all associated values fall between 82% and 85.7 % (81% and 84.8% for 1994-1996). The planned unavailability loss factor is 10.6%, and the unplanned unavailability loss factor is 5.9% on a worldwide average (respectively 11.8% and 5.9% for 1994-1996).
- For the 1994 to 1996 period, compared to the period 1991 to 1993, the PUF factor was very much the same (11.8 for 12.0); improvement came also from UUF (5.9 for 7.0%). Now, on the contrary, UUF is very stable, PUF moved from 11.8 to 10.6 %.
- The overall World\* availability/unavailability trend is given, through its planned (PUF) and unplanned (UUF) components, on Figure 4-4. Referring to the 1986-1990 survey, the global gain of + 4% for EAF comes from PUF (-1,9%) and UUF (-2,1%).
- The size effect does not appear very significant. This is true regardless of the fuel used and regions in question.
- On a regional basis, PUF is quite the same in all regions (all fuels), at about 10.5%. However, given a UUF value of 4.7% in Western Europe and 6.2% in North America, the level for "other countries" is  $UUF = 5.7\%$ .

Depending on the type of fuel used, the World\* sample presents a 3% difference in favour of solid fuels against liquid and gas fuels (84.5 versus 81.4). The PUF factor for coal is 9.8 % (12.3 % for liquid + gas), the UUF factor 5.7 % (6.3 % for liquid + gas). The mode of operation of these units (base load, or intermediate load) is possibly the main explanatory factor. Coal plants are mostly base-loaded, what imposes as far as possible reduced values for PUF and UUF. Fuel and gas plants are often operated in a load following mode, and shorter planned outages durations are not relevant.

### Japan

Japan provided an extensive set of data besides the 1997-1999 survey (tables C13, C14 and C15) completely following the WEC direction, i.e. the same kind of data set provided for the 1994-1996 survey.

The available information, which for the annual tables started in 1979, shows clearly the specific characteristics of operational experience of Japan. Therefore, the results are country based and not included in the World\* results to keep consistency with studies previously performed.

The set of Japanese base-load fossil-fuel plants represented 148 units and 80,200 MW in the period 1997-1999. The average EAF of these plants is 82.9% (81.2% for the previous survey), while PUF equals 16.2 % (17.7 %) and UUF, 0.9 % (1.1 %). As already stated, although the global average result for energy availability factor is in the same order of magnitude as the World\* sample (83.5 %), the balance is again completely different for PUF and UUF. It is clear that the potential for improvement comes from the reduction of PUF factor (- 1.5 %) while maintaining the UUF factor at a low level, or even trying to improve it (-0.2 %).

The fact that PUF factor for Japan moved from 18.7 % in 1994 to 15.3 % in 1999 shows very clearly that a very cautious, but positive policy, has been implemented to achieve better operating optimization in these units. As base-load units, they must operate to the maximum (optimum) use of their capabilities, therefore, it seems that the extension of such a careful policy, facing a more demanding market, could reveal additional availability improvements.

The diagonal table (Appendix C22) shows that the cumulative energy availability factor for Japan were kept steadily at the 82-84 % level, as well as the annual average EAF results. This means a perfect consistency of behaviour for the past operating policy of Japanese power plants. As explained earlier, the tentative to reduce the PUF factor to values more widely observed in the external World\* sample would allow to free up potential gains that are already in progress.

### China

China provided availability and unavailability data in the format required by the WEC/PGP Committee for the period 1997-1999 in Appendix C16. Data had been also provided for the period 1994-1996.

The comparison between the two surveys shows a continuous and steady improvement for Chinese base-load power plants using fossil fuel: three-year average for PUF moving from 9.9 % to 8.3 %, and for UUF from 4.7 % to 2.6 %. As a result, the EAF factor reached 89.1 % (from 85.5 %, previous survey), for a total sample of 125 000 MW (more than 600 units). This shows that it is technically feasible to reach the 8 - 9 % level for PUF, while keeping UUF in the 3 - 4 % range, as an average for a large fleet of units. The average energy availability factor (EAF) would be in the range 88 to 90 %.

**Russia**

Russia has also provided data on availability and unavailability for the current survey (see Appendix C17). The average EAF is 80.5 % for the period 1997-1999, represented by 209 units, 60 000 MW. The average unavailability for this period of time are 16.3 % for PUF and 3.2 % for UUF. The low rate of unplanned unavailability (3.2 % compared to 5.9 % for World\*) is offset by a relatively high rate of planned unavailability (16.3 %) corresponding to about 2 months of average annual shutdown duration for overhaul and maintenance. It seems there is room for improvement by reducing the duration (or frequency) of planned shutdowns, while maintaining a low unplanned unavailability factor (UUF). In fact, this seems to be already in progress, as the PUF factor moved from 18.8 % in 1997 to 13.9 % in 1999, keeping UUF within very reasonable limits (< 3.5 %).

**4.2 AVAILABILITY ACCORDING TO UNIT AGE**

The energy availability factors according to age of unit are given in the tables in Appendices C18 to C22. According to them, units are reaching their asymptotic value, expressed in terms of cumulative energy availability,  $F_c$ , after the first few years of operation. Furthermore, there is no discernible ageing effect: over 25 years, there is a loss of less than 1% from the third to the twenty-eighth year in cumulative values. Nevertheless, that observation should be treated with great caution, given the small size of the samples shown in the tables when age becomes a significant factor.

For steam turbines (all fuels), the value of  $F_c$  (expressed in %) is presented in Table 4-3.

Table 4.3 Steam Turbines, Cumulative Energy Availability Factor

$F_c$ (%)	All size
World *	78.6
North America	78.5
Western Europe	82.5
Japan	82.0
Other Countries	77.4

**4.3 CONCLUSIONS FOR FOSSIL-FIRED GENERATING PLANTS**

The lessons learned through this survey, which covers some 45 countries around the world, are consistent with those presented at the Tokyo and Houston Congresses, six and three years ago. For the current data survey period, 1997-1999, steam turbine units reveal a further 1.2% improvement in plant availability in comparison with the average results for 1994-1996. This improvement is mainly due to a reduction in planned unavailability.

Over the last 10 years, fossil fuel plants gained 4% on Energy Availability Factor, representing a 2.1% gain on unplanned unavailability, and a 1.9% gain on planned unavailability (Figure 4-4).

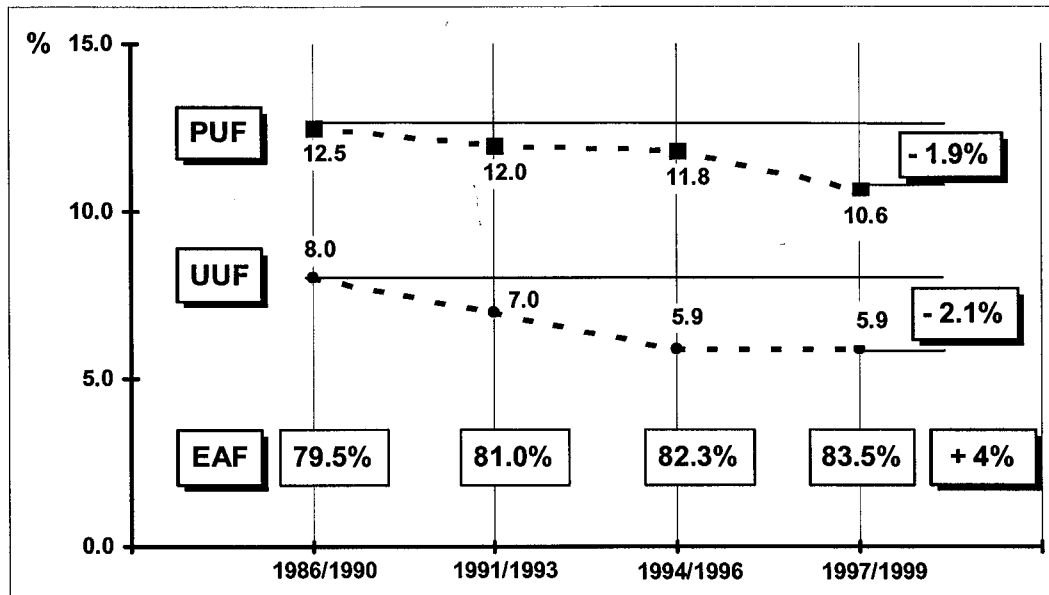


Figure 4-4 Average World\* Energy Unavailability Factors

This clearly demonstrates a better usage of planned outages (duration, content, frequency, etc.), while preventive maintenance performed might be increasingly better adapted to real needs and quality of equipment in operation.

Furthermore, the differences between regions around the world, concerning both installation size and fuel types used, are no longer pertinent from a statistical viewpoint, as was underscored at previous Congresses. Clearly, a more sophisticated statistical analysis would mean taking into account more specific factors, enabling uniform installation “families” to be defined. This would imply statistical monitoring of availability performance on a unit-by-unit basis, which is not the case in this type of survey which shows cumulative results for facilities whose design parameters, in particular size and fuel type, are increasingly less significant.

On the whole, this survey enables to identify results and set objectives. It also demonstrates the indisputable progress made by electricity producers around the world. The issue of integrated performance (technical, economic and environmental) is today a concrete challenge.

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 emulation and, in particular, encourage active participation in cooperation and exchange efforts which may be proposed in the future by the WEC Committee on Performance of Generating Plant.

Nevertheless, additional factors have to be taken into consideration, as there is a stronger need to reach a global but full picture of power plant performance, facing the grid and the needs of the users. 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.

The WEC PGP Committee will consider all these relevant factors to continue producing statistics that will remain of interest – and maintain an emulation culture – for all electricity producers worldwide.

## 5. GAS TURBINE AND COMBINED CYCLE

### 5.1 INTRODUCTION

A Committee Paper on the Exchange of Availability / Performance Data on Gas Turbine and Combined Cycle Generating Plant, was presented at the 15<sup>th</sup> WEC Congress and included in the WEC 1992 Monograph on Availability of Thermal Generating Plant [Ref. 7]. At the 16<sup>th</sup> WEC Congress in 1995, the first report was presented with the results of the data collection trials following the proposed standardized formats. The recommendations following the 1995 paper was to expand the participating countries to include as many countries with base load gas turbine and combined cycle plant. Following the 17<sup>th</sup> WEC Congress in 1998 further recommendations included using the same data collection scheme as for the fossil and nuclear thermal power generating plant.

The current report presents the results of the data collection efforts over the last three years, where the participating countries have expanded from ten countries in 1998 to sixteen countries in 2001 and the total data set has grown significantly. The countries participating in the current three-year data set are Argentina, Egypt, Finland, Hong Kong, Kenya, Indonesia, Japan, Korea, Mexico, New Zealand, Pakistan, Slovenia, Syria, Taiwan, Thailand, USA and Venezuela. Additional countries included in the total data set since the start of data collection in 1992 are Iran, Ireland, Malaysia and Netherlands.

The data collected represents several years of operating history. The time window represented spans the period from 1984 to 2000. Not all countries were able to submit data for all years in that period and the results shown represent all the data, the results from the current period of 1997 – 1999 and updated results from 1991 – 1993 and 1994 - 1996. The following discussion will cover a review of current definitions and terminology and then show the availability statistics developed from the collected data.

The organization of this part of the report is in four sections. Section 5.1 is the introduction, Section 5.2 discusses the definitions and terminology, Section 5.3 shows the availability statistics developed from the collected data, Section 5.4 contains the conclusions of the current data collection effort and recommendations for the expansion of the data collection effort to include additional countries for the next reporting period.

### 5.2 DEFINITIONS AND TERMINOLOGY

The definitions and terminology, applicable to gas turbine and combined cycle plant were discussed in the 1992 Joint UNIPEDE/WEC Committee Paper, No. 1.3. The data collection effort for base load gas turbine and combined cycle plant is still in the developing stages. This section will review some of the major items of definitions and terminology to allow a better understanding of the results.

The data collection form for the annual availability summary report is shown in Table 5-1. The size classes are 30 - 75 MW and 76 - 150 MW for gas turbine plant and 100 - 200 MW, 201 - 300 MW and higher than 300 MW for combined cycle plant. For countries with time-based availability data collection systems, unavailability data due to partial outages was requested in addition to the data items shown.

The size classes are based on ISO ambient conditions (sea level, 60% RH and 15°C). Planned Unavailability (PUF) consists of planned partial and full outages scheduled well in advance. Unplanned Unavailability (UUF) consists of all unplanned partial and full outages requiring shutdown and repair.

### 5.3 AVAILABILITY STATISTICS FROM COLLECTED DATA

#### 5.3.1 Data Sample

The data used was contributed by Argentina, Egypt, Finland, Hong Kong, Kenya, Indonesia, Japan, Korea, Mexico, New Zealand, Pakistan, Slovenia, Syria, Taiwan, Thailand, USA and Venezuela. Additional countries included in the total data set since the start of data collection in 1992 are Iran, Ireland, Malaysia and Netherlands.

Each country contributed several years of data. Most of the respondents submitted the data utilizing the data definitions shown in Table 5-1 for gas turbine and combined cycle plants. Some countries submitted data in the Lascar format, which is also used for data collections to the fossil steam plant data base.

Table 5-1 Template for Annual Availability Summary Report - Gas Turbine Plant

Size Class (MW)	Number of Units in Class	Total (MW)	Average Unavailability %		Average Total Unavail. (%)	Average Total Avail. (%)
			PUF	UUF		

Significant amounts of data were available for the results development and the statistical usefulness of the current set of results is improving compared to the results shown in the 1998 report. The data set is still too small to allow meaningful groupings by fuel, region and size. Eventually, after a few more three-year periods, the report to the WEC Congress may include regional, fuel and size specific comparisons.

## 5.3.2 Results based on the primary energy availability data

**Gas Turbine Plant**

The data set describing the energy availability statistics for gas turbine plant for all years collected is shown in Table 5-2. Data was collected for a total of 691 unit-years and the average unit size was 64 MW. Since there are many additional plants included in the current data set, differences between the results in the 1995 report with the results shown here may not be easy to explain. The following comments are only included to indicate the differences.

The energy availability factors show some sensitivity to size. The data for the components of unavailability appears to have some relationship to size. The units in the smaller size class show higher unavailability due to planned outages than the larger size class, and similar unavailability due to unplanned outages. These differences could be attributed to different operations and maintenance practices in different power companies and also to variations in duty cycle between the two size classes.

Table 5-2 Availability Statistics for Gas Turbine Plant - Cumulative for All Years Collected

Size Class (MW)	Unit-years	Average (MW/unit)	Availability %	Unavailability (%)		
				PUF	UUF	Total
30 - 75	475	45	80.65	11.54	7.81	19.35
76 - 150	216	107	86.13	7.08	6.79	13.87
All Sizes	691	64	83.50	9.22	7.28	16.50

The results show a lower energy availability of 80.65 % for the smaller size class compared to 81.23 % in the 1998 report, while the larger size class shows an increase from 84.57 % in the 1995 report to 86.13 % this time. The unplanned energy unavailability factor (UUF), now includes the unplanned maintenance reported specifically in the 1998 report, increased from 5.39 % to 7.81 % for the smaller size class, and improved from 7.04 % for the larger size class in 1998, to 6.79 % this time.

Figure 5-1 shows the availability statistics for gas turbine plant in the 30 - 75 MW size class for the time periods of 1991-1993, 1994-1996, 1997-1999, and for all years collected. The first two time periods were recalculated since some countries contributed new data for those time periods.

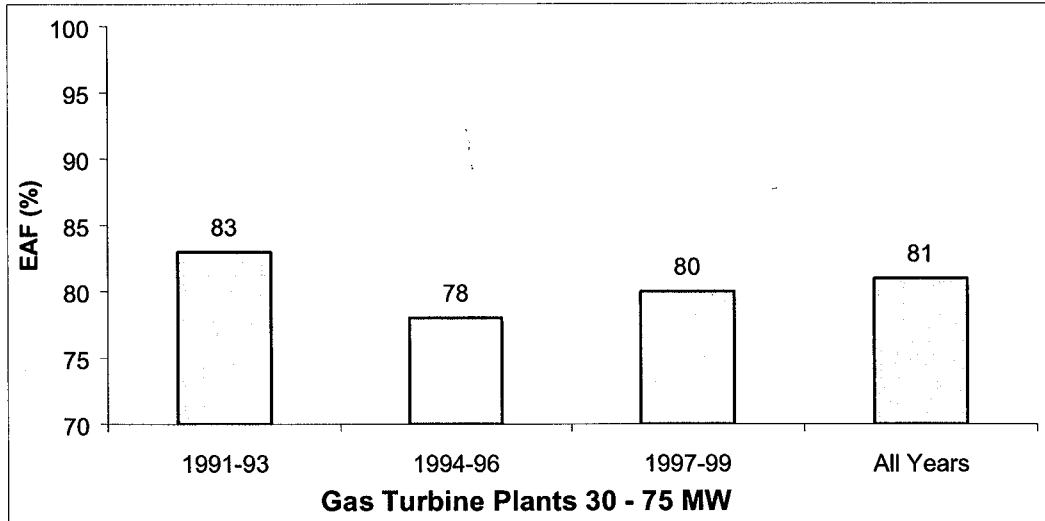


Figure 5-1 Three-year Average Energy Availability Factors (%)

Figure 5-2 shows the availability factors for the 76 - 150 MW size class in the same format. It is interesting to note that the rolling three-year availability factor for the 30 - 75 MW group of gas turbines shows a definite decline since the 1991-1993 period, while the larger size class shows an improving performance over time.

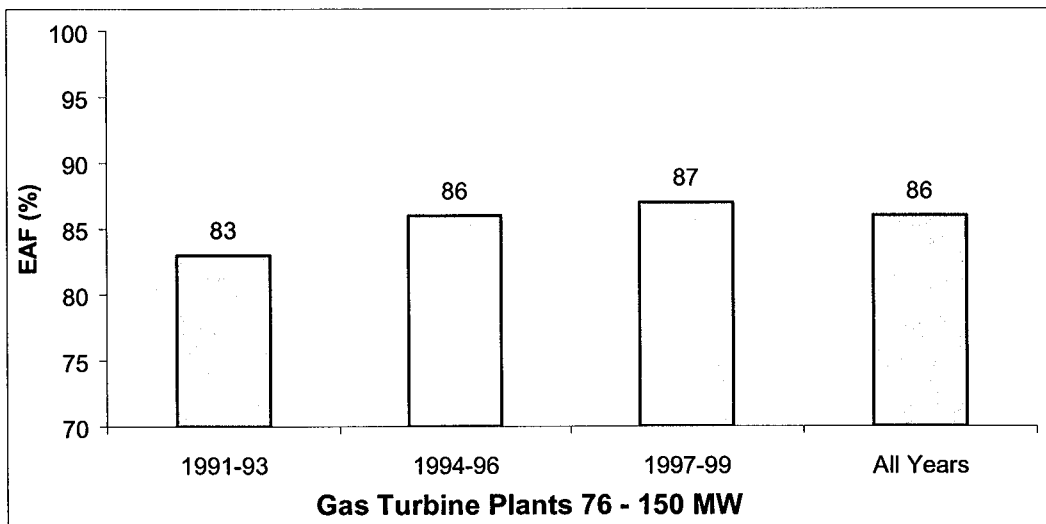


Figure 5-2 Three years Average Energy Availability Factors (%)

The unplanned energy unavailability factors including all outages that are not planned outages for the same size classes and time periods are shown in Figures 5-3 and 5-4. For the unplanned energy unavailability factors, the smaller gas turbine size class shows a deteriorating trend. The larger gas turbine size class shows a much more stable performance.

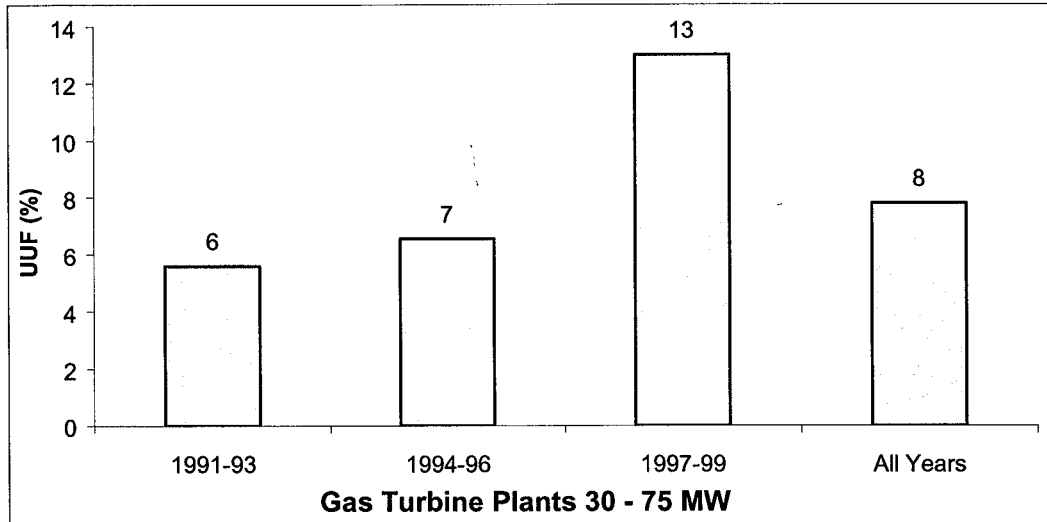


Figure 5-3 Three-year Average Unplanned Energy Unavailability Factors (%)

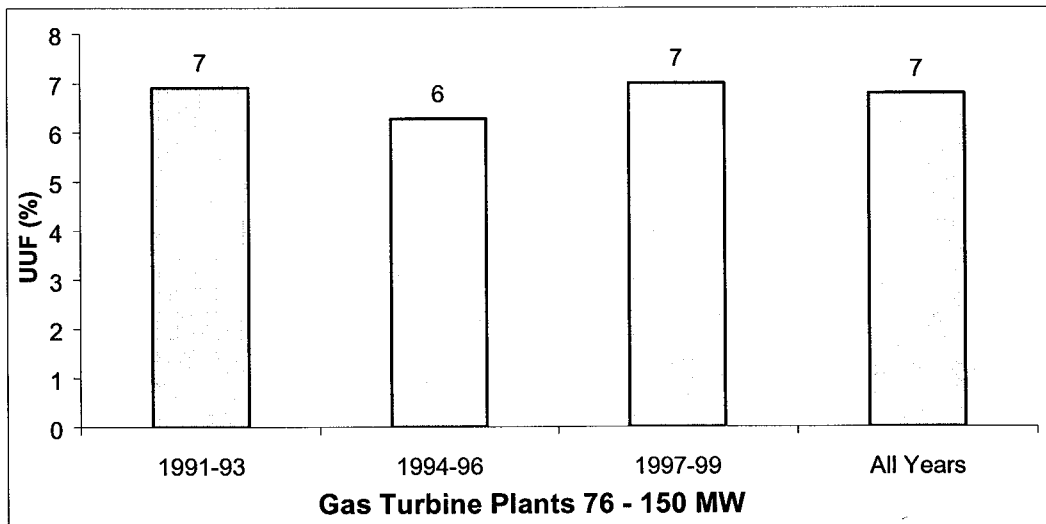


Figure 5-4 Three-year Average Unplanned Energy Unavailability Factors (%)

### Combined Cycle Plant

The data set describing the availability statistics for combined cycle plants for all years collected is shown in Table 5-3. Data were collected for a total of 1306 unit-years and the average unit size was 222 MW. Just as for the data collected for the gas turbine plant, there are many additional plants in the current data set, compared with the 1998 report, and differences are shown and discussed, but no attempt is made to explain the possible reasons for the differences.

Table 5-3 Availability Statistics for Combined Cycle Plant - Cumulative for All years Collected

Size Class MW	Unit-years	Average MW/unit	Availability %	Unavailability (%)		
				PUF	UUF	Total
101 - 200	682	138	84.48	13.55	1.97	15.52
201 - 300	346	241	84.86	10.99	4.16	15.14
> 301	278	404	85.37	8.73	5.90	14.63
All Sizes	1306	222	84.93	10.94	4.13	15.07

It appears that the energy unavailability factors for combined cycle show no sensitivity to size. In the case of the combined cycle plant, it is interesting to note that the high unavailability due to planned outages for the smallest size class, reflects in a lower unplanned outage factor, even though the total energy unavailability factor is still higher for the smallest size class.

Comparing to the 1998 report, the current results show slightly lower energy availability factors for all size classes. The 101-200 MW size class currently shows a 84.48% energy availability factor compared to 84.96% in the 1998 report. For the 201-300 MW and 301 MW and higher size classes, the current results are 84.86% and 85.37% versus 87.22% and 86.07% in the 1998 report. Since the total data set for combined cycle is much larger now than in 1998 and there are many new countries contributing data, it is not possible to comment on these differences.

When comparing the unplanned energy unavailability factors between the 1998 report and now, there are no significant changes for the two smallest size classes, 1.97% now versus 1.57% in 1998 for 101-200 MW and 4.16% versus 3.74% for the 201-300 MW class. For the larger size class, however, there is a significant deterioration of 5.90% now versus 2.99% in 1998.

Figure 5-5 shows the average three-year availability factors for combined cycle plant in the 101-200 MW size class for the time periods of 1991-1993, 1994-1996 and 1997-1999. The improvement from the 1994-1996 time period has reversed and the results from the 1997-1999 time period is even below the 1991-1993 time period.

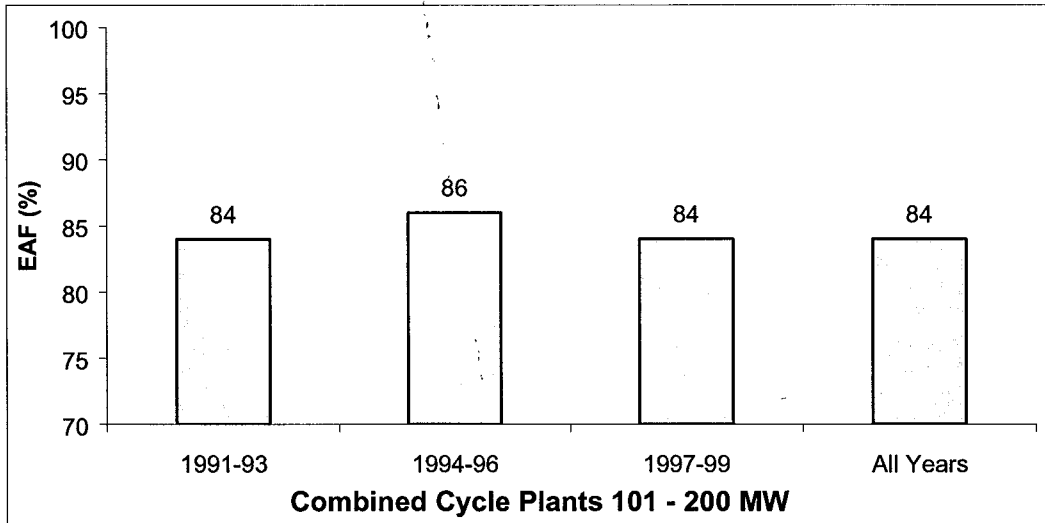


Figure 5-5 Three-year Average Energy Availability Factors (%)

Figure 5-6 shows the average three-year energy availability factors for combined cycle plant in the 201-300 MW size class. The pattern is similar to the smaller size class discussed above.

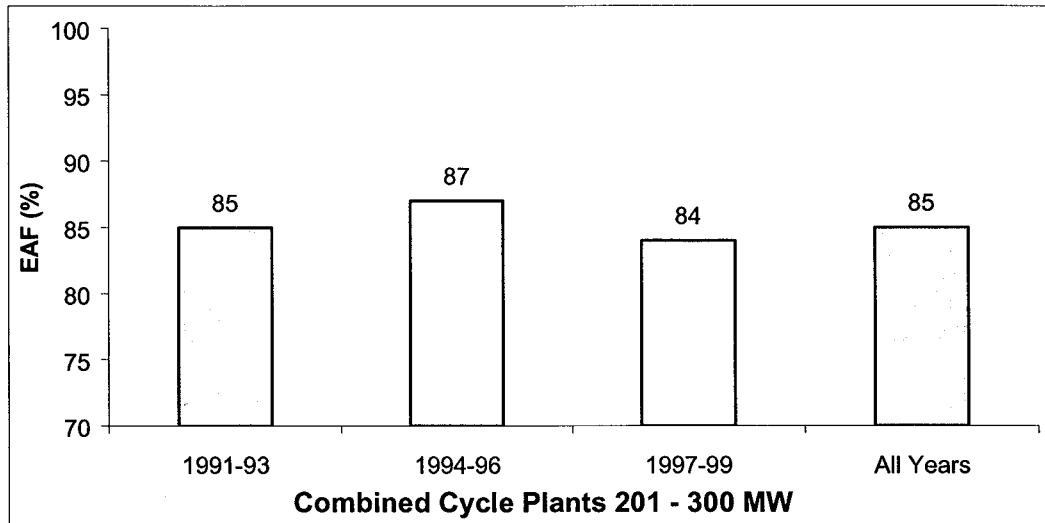


Figure 5-6 Three-year Average Energy Availability Factors (%)

The results in the largest size class, over 300 MW (Figure 5-7) again shows a deteriorating performance in the 1997 – 1999 time period following an encouraging improvement in the 1994 – 1996 period.

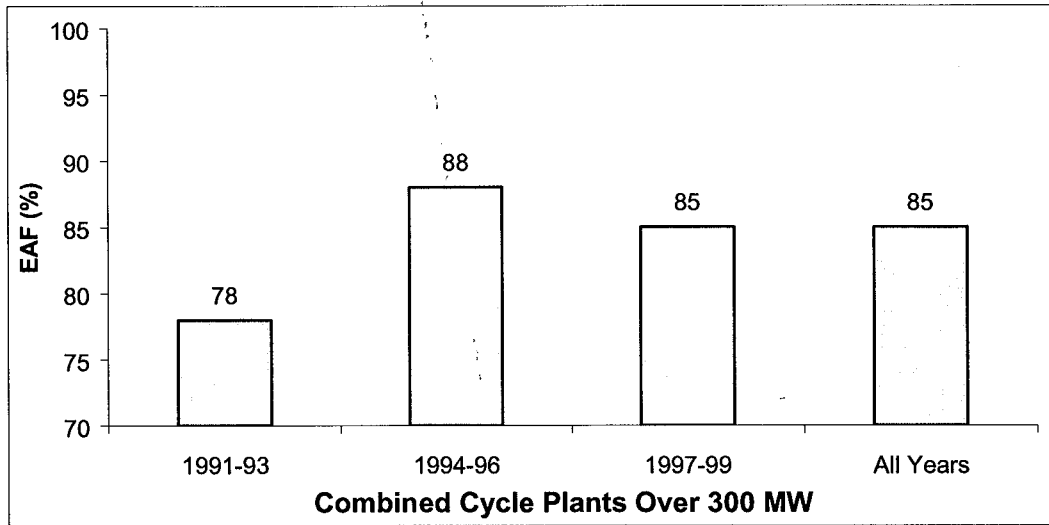


Figure 5-7 Three-year Average Energy Availability Factors (%)

The three-year average unplanned energy unavailability factors for the same class sizes and time periods are shown in Figures 5-8, 5-9 and 5-10.

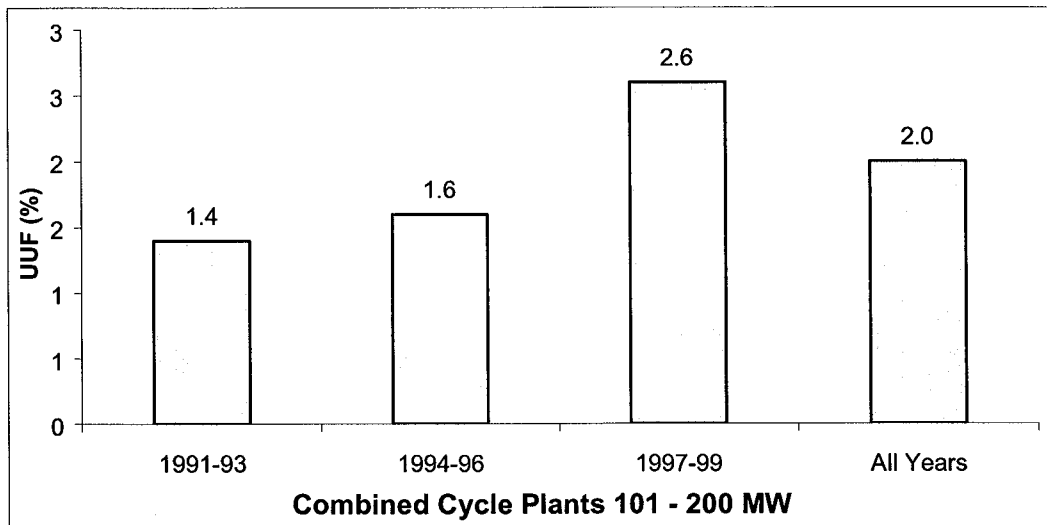


Figure 5-8 Three-year Average Unplanned Energy Unavailability Factors (%)

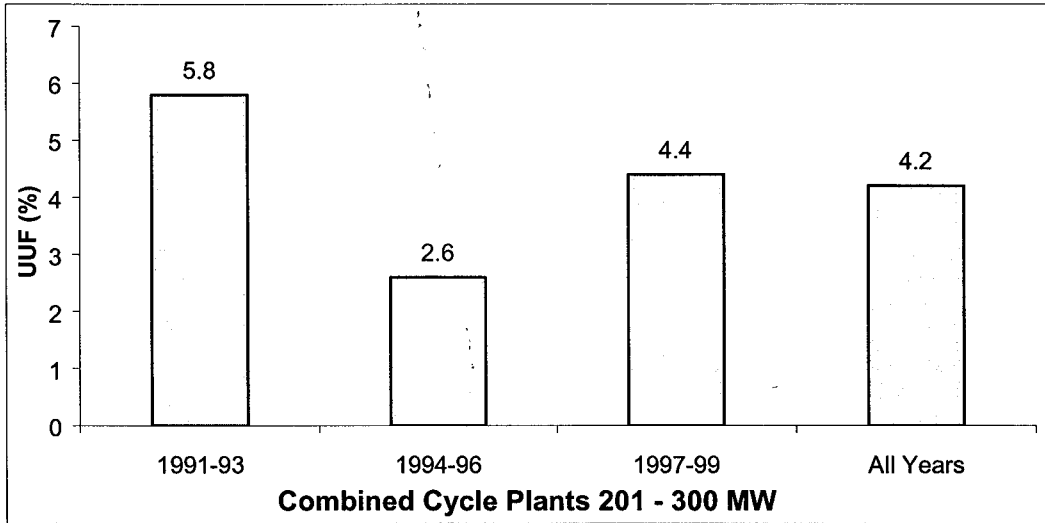


Figure 5-9 Three-year Average Unplanned Energy Unavailability Factors (%)

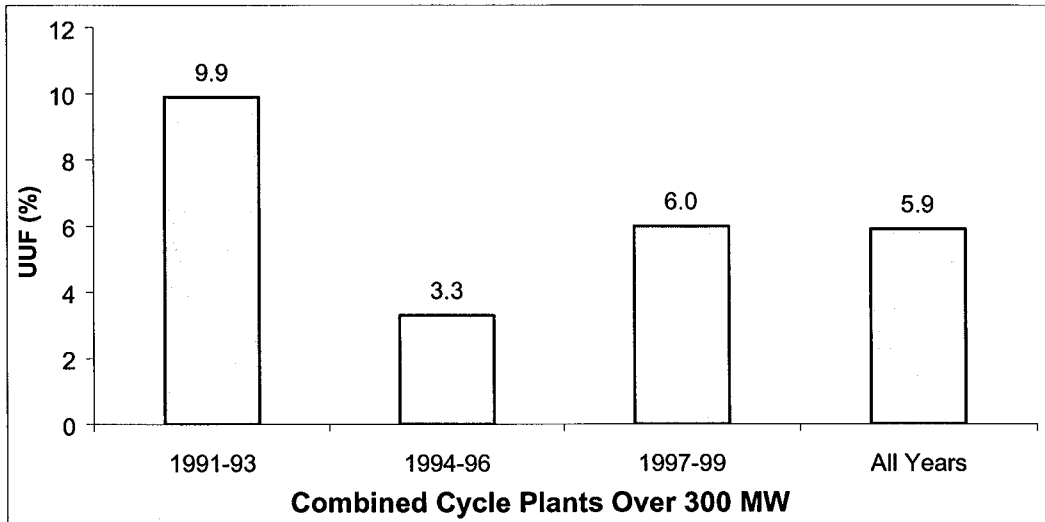


Figure 5-10 Three-year Average Unplanned Energy Unavailability Factors (%)

The results from the average three-year unplanned energy unavailability shown above in Figures 5-8 to 5-10 are showing deteriorating results for all size classes. The very significant increase in participating units makes it very difficult to conclude underlying reasons for this deterioration.

#### 5.4 CONCLUSIONS FOR GAS TURBINE AND COMBINED-CYCLE GENERATING UNITS

The data collection and results development from the last three-year period have been successful. The significant increase in the database and participating countries will allow an improved ability to develop meaningful results. As the magnitude of this data base further increases by adding more countries and additional years of data, it will be possible to use this database as a valid reference for an energy availability factor expectation, particularly useful for countries in the early stages of employing gas turbine plant and combined cycle plant as part of their power systems.

The quality and consistency of the data reporting have been improving and it is expected that as additional countries choose to participate, the definitions and methodology as described in Section 5.2 will remain as a consistent base for data collection.

## 6. NUCLEAR POWER GENERATING UNITS

The statistics presented in this section are based on data collected by the International Atomic Energy Agency (IAEA) for its Power Reactor Information System (PRIS).

### 6.1 NUCLEAR POWER INFORMATION AT THE IAEA

#### **The Power Reactor Information System (PRIS)**

Information and data on nuclear power reactors have been collected by the IAEA since its establishment. PRIS covers two kinds of data: general and design information on power reactors, and data on operating experience with nuclear power plants. General and design information covers data on all reactors that are in operation, under construction, or shutdown in the world. Operating experience data cover operating reactors and historical data on shutdown reactor since beginning of commercial operation.

PRIS covers the largest amount of worldwide statistical information on operating experience. Although there are other similar data banks in existence, which could sometimes be referred to, the IAEA PRIS is considered the most complete and authoritative source of statistical data on the subject area.

PRIS serves also to easily 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 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, safety features, existence of safety analysis report and of emergency plans, plant environment, etc. This additional information on plant characteristics, which provides better overview of the plant design and mode of operation is being implemented in PRIS.

#### **Uses of PRIS**

The IAEA's PRIS can be used to assess nuclear power performance through many different indicators and outage causes in a systematic and homogeneous manner. It covers the largest amount of worldwide statistical information on operating experience. The data contained in the system make it especially useful for identifying problem areas and overall trends and the amount of operating experience data available permits statistical analysis to be made.

Currently, the principal nuclear power performance indicators cover: plant availability and unavailability; planned and unplanned outages; nuclear safety related events; unavailability of safety systems and support functions; worker safety related events; radiation exposure; fuel reliability; and volume of radioactive waste. Among those, PRIS provides information on energy availability factor, planned unavailability factor, unplanned unavailability factors due to causes in the plant and external to the plant, load factor, operating factor, unit capability factor, unplanned capability loss factor, and recently on the number of scrams. Statistics on planned and unplanned outages including causes of outages are also possible.

Care should be taken not to give priority to a single performance indicator as this could distort the overall impression. 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 many products to the IAEA Member States and international organizations: such as MicroPRIS, PRIS-PC (front-end tool interface with on-line connection to PRIS through the Internet), PRIS on CD-ROM, and through a public Internet site at the address: <http://www.iaea.or.at/programmes/a2/>. Currently, these products are distributed to more than 700 organizations. In addition the IAEA Secretariat answers daily to a considerable number of ad-hoc requests on nuclear power plants information and statistics.

## 6.2 STATUS OF NUCLEAR POWER WORLDWIDE

[3]

A total of 438 nuclear power plants were operating around the world at the end of 2000, according to data reported to the IAEA's Power Reactor Information System. The plants had a total net installed capacity of 351 GW(e). Also during 2000, six nuclear power plants representing 3056 MW(e) net electric capacity were connected to the grid, one in Brazil, one in the Czech Republic, three in India and one in Pakistan. (See appendix N1)

Additionally, construction of five new nuclear reactors started in 2000 - one in China, two in India and two in Japan, bringing the total number of nuclear reactors reported as being under construction to 33.

Nuclear power provides about 16% of global electricity, with about 83% of nuclear capacity concentrated in industrialized countries. The ten countries with the highest reliance on nuclear power in 2000 were: France, 76.4%; Lithuania, 73.7%; Belgium, 56.8%; Slovak Republic, 53.4%; Ukraine, 47.3%; Bulgaria, 45%; Republic of Korea, 40.7%; Hungary, 40.6%; Sweden, 39% and Switzerland, 38.2%. In total, 17 countries relied upon nuclear power plants to supply at least a quarter of their total electricity needs.

Worldwide in 2000, total nuclear generated electricity increased to 2448.40 terawatt-hours. Cumulative worldwide operating experience from civil nuclear power reactors at the end of 2000 exceeded 9800 reactor-years.

In North America, where 118 reactors supply about 20% of electricity in the United States and 12% in Canada, the number of operating reactors has declined slightly. In Western Europe, with 150 reactors, overall capacity is likely to remain at or near existing levels in the coming years. In Central/Eastern Europe and the Newly Independent States, with 68 reactors, a few partially built plants are likely to be completed, while aging units are being shut down. Only in the Middle East, Far East and South Asia, with a total of 94 reactors at present, are there clear plans for expanding nuclear power, particularly in China, India, the Republic of Korea and Japan.

Nevertheless, the prospects for nuclear power in the next future might change. Some US utilities have showed intentions to engage in building new plants. The innovative reactor designs are under development in several countries with goals of low capital costs, short construction periods, high performance and enhanced safety might play a role in the future, specially the small to medium size reactor (SMR) type, with construction based on factory built structures and components including complete modular units for on-site installation. For

example, the Pebble Bed Modular Reactor (PBMR, 110 MWe gas cooled reactor), is proposed to be built in the near future in South Africa.

### 6.3 WORLDWIDE ENERGY AVAILABILITY AND UNAVAILABILITY

#### 6.3.1 Approach used for the Availability Analysis

The statistics on nuclear power plants cover non-prototype units in operation or shutdown at the end of 2000, i.e. plants with more than 100 MW(e). The information reported to the IAEA Power Reactor Information System up to end of June 2001 was the basis for this survey.

Although, energy availability and unavailability factors are presented at this report for the year 2000, data analysis for nuclear power plants is made for the three-year period (1997-1999) to be consistent with the statistics on conventional thermal (Chapter 4) and combined cycle/gas turbine plants (Chapter 5) presented in this report.

The basic performance indicators for this study are the Energy Availability Factor (EAF) and the Planned (PUF) and Unplanned Energy Unavailability Factors (UUF). The Energy Availability Factor is the ratio of the actual and potential energy generation (net) in a given period, expressed as a percentage of the maximum energy that could have been produced during that period by continuous operation at the reference capacity. Energy losses are planned if they are scheduled at least four weeks in advance. Planned energy losses are considered to be under plant management control and include losses due to planned outages for refuelling, maintenance, testing, etc. Unplanned energy losses include losses due to unplanned outages for maintenance, testing, repair, etc. and due to causes beyond the control of management (external causes).

The availability and unavailability of nuclear power plants are here presented according to their type, region and age.

The following groups has been established for observing trends on energy availability and unavailability factors:

#### Selection of Regions (R):

World: all units in the world

North America: Canada and the USA

Latin America: Argentina, Brazil, Cuba and Mexico

Western Europe: Belgium, Finland, France, Germany, Netherlands, Spain, Sweden, Switzerland and the United Kingdom

Eastern Europe: Bulgaria, Czech Republic, Hungary, Kazakhstan, Lithuania, Russian Federation, Slovak Republic and Ukraine

Middle East and South Asia: India and Pakistan

Far East: China, Korea Rep. and Japan

Africa: South Africa

This classification is in accordance with the International Atomic Energy Agency grouping of countries and geographical areas [3].

Period of Observation

The period of observation considers:

P = 0: yearly observation

P = 1: average over the years 1991, 1992, 1993

P = 2: average over the years 1994, 1995, 1996

P = 3: average over the years 1997, 1998, 1999.

P = 4: average since commercial operation and up to 2000 (lifetime).

The period of observation P = 1, 2 and 3 are used to compare trends on availability and unavailability presented in the two previous Triennial Reports (WEC Congresses in Tokyo and Houston) with the current three years analysis.

In an attempt not to make conclusions based on individual results, samples with less than 10 units are not considered. The availability and unavailability statistics considered only non-prototype units, i.e., units with capacity bigger than 100 MW(e). Also, the GCR and AGR type of reactors are not considered in the analysis.

6.3.2 Sustained Improvement in Plant Performance Worldwide

**Worldwide Results**

There has been a steady improvement in the World Energy Availability Factor as shown in Figure 6-1. The EAF grew from about 73% in 1990 to 81% in 1999, and achieved 82.1% in 2000.

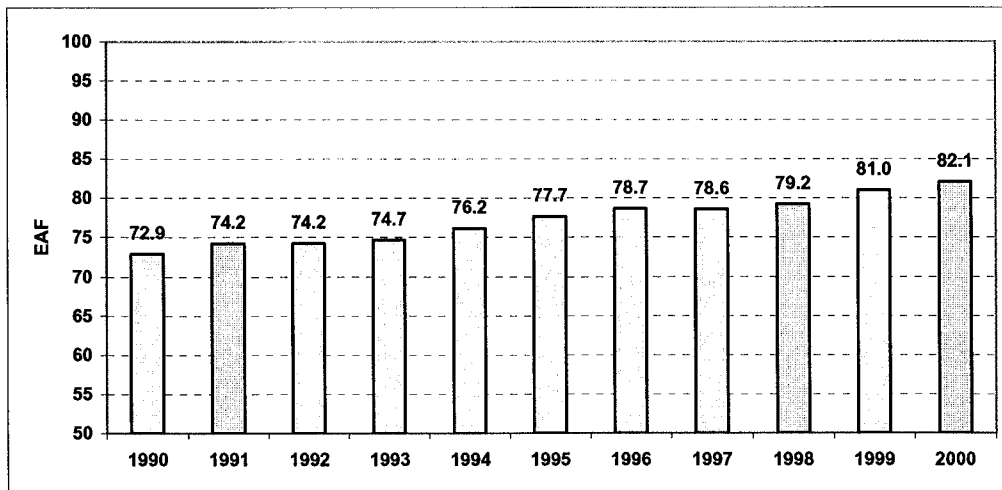


Figure 6-1 World Energy Availability Factors

The number of plants presenting higher energy availability factors (greater than 75%) also has increased. In 2000, 74 out of 438 operating nuclear power plants presented energy availability factor between 70 and 79% and 278 plants presented EAF higher than 80% (Figure 6-2).

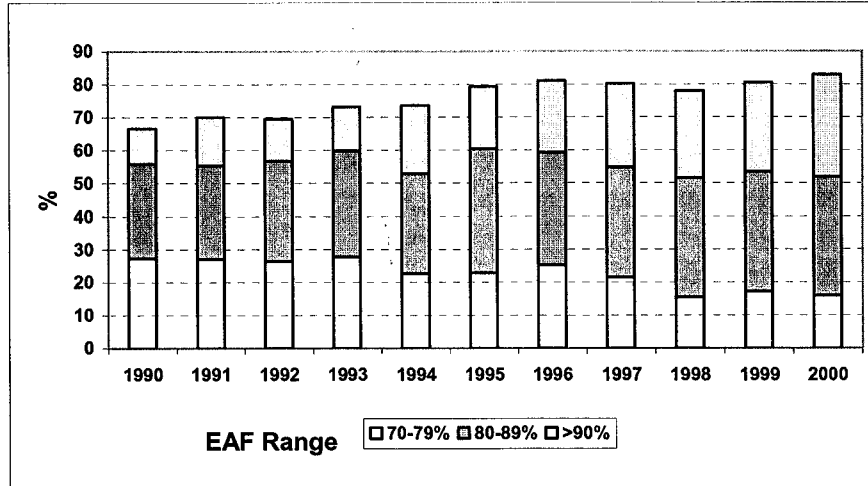


Figure 6-2 Distribution of Reactors with High Availability Factor

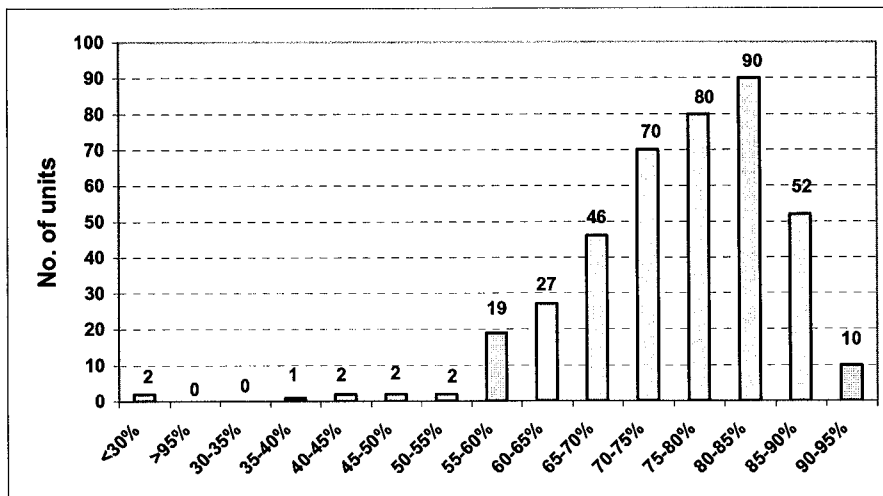


Figure 6-3 Distribution of Units According to Energy Availability Factor in 2000

The cumulative world energy availability factor up to 2000, since beginning of commercial operation and for non-prototype reactors, is 74%, while the planned energy-unavailability factor (PUF) is 16%.

There is a steady decrease in both planned and unplanned energy unavailability factors over the last years indicating continuing improvement in plant maintenance management (Figure

6-4). The average planned energy unavailability factor decreased continuously from about 17% in the period 1991-1993 to 15.6% in 1994-1996 and achieved 13.9% in 1997-1999. The improvement in the unplanned energy unavailability factor was also significant. Although the cumulative average UUF (since beginning of commercial operation) is 7%, it decreased from 11% in the period 1988-1990 to 6.5% in the last three years period (1997-1999) and achieved 5% in 2000. Moreover, considering only planned and unplanned energy losses under the plant management control, the values decrease to 4%.

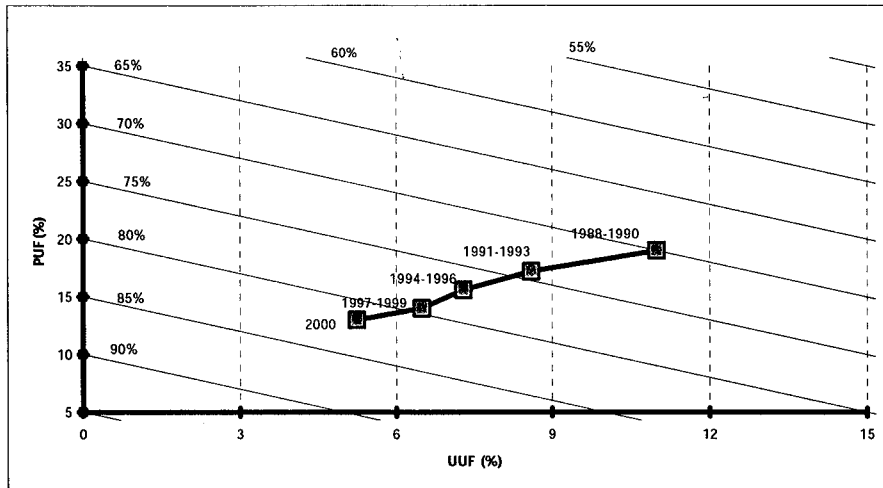


Figure 6-4 Average Availability and Unavailability Factors (three-year periods)

These values show the efforts made by the nuclear industry for a safe and reliable 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 it has also contributed to optimise operation of nuclear power plants in all its aspects: safety, reliability and economics.

However, the sustainable improvements in energy availability can be attributed to a process of learning from experience: a number of initiatives taken by the Member States and the Agency have a significant role in the achievement of sustained improvement in the overall performance of the plants.

**Survey by Reactor Type**

A survey by reactor type shows that there is considerable increase in the availability of BWR and PWR units. The PWR units have improved the energy availability factor from 73% in 1990 to 84% in 2000. The three years average also increased considerably from 76% between 1991-1993, to 80% in 1994-1996 and achieved 82% in 1997-1999. In 2000, the average EAF of all operating PWR units was 84%. For PWR units, the three years average of planned energy unavailability factor (PUF) was 11% in the period 1997- 1999, while the unplanned

energy unavailability factor (UUF) was 6%. In 2000, 36 PWR units presented EAF higher than 90%.

The BWR units also increased the energy availability factor from an average of 68%, in 1988-1990, to 77% in 1994-1996 and 81.5% in 1997-1999. In 2000, the average EAF of all operating BWR units was 85% and 34 out of 91 units presented EAF higher than 90%.

Many PWR and BWR units have optimised the frequency of refuelling outages. They now operate with longer fuel cycles. Others have implemented outage strategy, 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.

Since 1990, the average energy availability factor of PHWR units varies from 65% in 1990 to 80% in 2000. Since 1997, the EAF has continuously recovered and increased. The last three years (1997-1999) average is 73%. The unplanned energy unavailability factor has also decreased considerably and achieved 6.5% in 2000.

The WWER units presented a cumulative EAF of 70% up to 2000. Nevertheless, the yearly values have been below this reference. The last three years average (1997-1999) is 67%. The availability of WWER units, as well as the LWGR (or RBMK), shows the impact of longer planned outages for refurbishment and back fittings since 1990. It is to note that the Finish units of WWER type are included in this group, but, on the contrary, they have always presented very high EAF. They are also among the lowest planned and unplanned energy unavailability factors in the world.

The LWGR units presented a decrease in the availability, with high planned availability factor.

Figure 6-5 presents the average energy availability values for the period 1997-1999 by reactor type. The energy unavailability factors by reactor type are presented in Appendices N8 to N12.

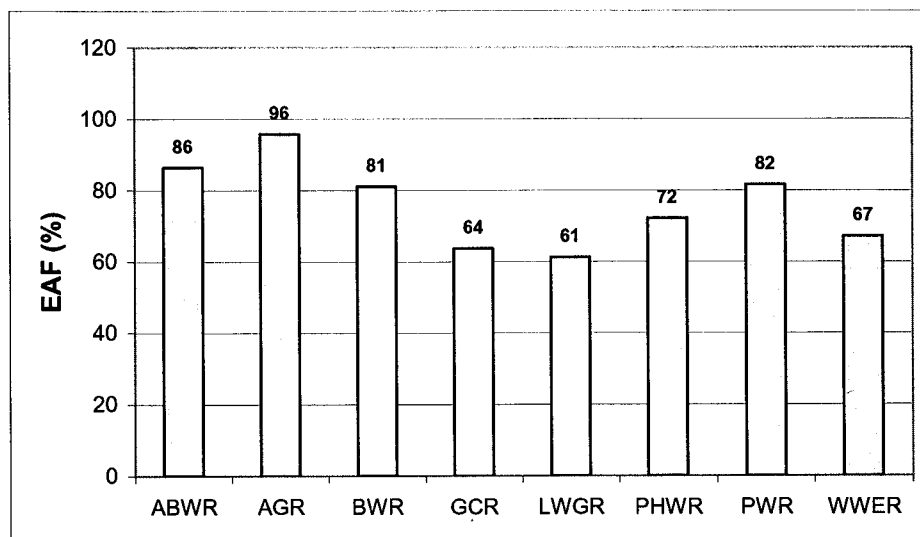


Figure 6-5 Energy Availability Factors by Reactor Type (1997-1999)

### **Survey by Region**

The analysis of energy availability and unavailability values by region since the beginning of commercial operation (lifetime) and in the last years (1990-2000) is presented in the Appendix N15 to N21.

The results showed an increase in the yearly average of energy availability factor since 1990 in almost all world regions. In special, in North America the yearly EAF increased from 70% (1990) to 88% (2000). This increase is mainly due to the USA units (73% in 1990 to 88% in 2000), which have improved considerably its performance in the last years, and in less portion to the Canadian units which have increased the availability in the last 3 years. In Western Europe, the yearly EAF has also increased since 1990, although at a lower level. This could be due to the uncertainties given by the different country energy policy in the region.

In Eastern Europe, where the majority of units are of WWER and LWGR type, with the exception of the PWR unit operating in Slovenia, the yearly EAF is between 61 to 67% in the last ten years.

The plants in Latin America have also improved the EAF, although some variations and low values are found in some years, the plants have recovered in the last years.

The units in operation in the Far East present almost constant and high values of EAF. The EAF varies from 73% (1990) to 83% (2000)

It is to note that world regional analysis are difficult to be made 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.

### **Survey by Age**

The calculation of energy availability factor by age of reactor since the beginning of commercial operation up to 2000 shows that units have higher energy availability factor in the first year of commercial operation, to decrease in the subsequent years and achieve higher values again after the 5<sup>th</sup> year of commercial operation. The value is almost constant for some years. For reactors with more than 25 years of commercial operation the values of energy availability factor increases. The later results should be analysed in details, but it might show the learning from experience of older plants and other factors such as upgrade of capacity.

## **6.4 CONCLUSIONS FOR THE NUCLEAR GENERATING UNITS**

The average energy availability factor for nuclear power plants in the world has steadily increased from about 73% in 1990 to the current value, which is above 82%, with many utilities achieving significantly higher values.

The worldwide results present a steady decrease in both planned and unplanned energy unavailability factors over the last years indicating a continuing improvement in plant maintenance management. Therefore, it provides a good indication on improvements on plant reliability and safety in the last five years.

The results by reactor type show that there is a considerable increase in the availability of PWR and BWR mainly due to a decrease of the planned unavailability in the last three-years.

These results confirm the improvements in the worldwide energy availability factor, when compared with the results presented in the last surveys. Nevertheless, 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.

Many utilities are changing or going to changing their management strategies and addressing aspects, which require more attention to all areas. Some aspects have been identified as major recent industry transformations contributing to reduce costs: process changes (refuelling and other planned outage reductions), re-engineering and an aggressive self-assessment and capital investments. The implementation of these strategies together with the process of learning from experience contributed among others to: the decrease of unplanned outages; better outage management strategies which led to a reduction of the planned outage time (planned maintenance); effective failure prevention programmes including effective maintenance and on-line preventive maintenance, which help identify in advance equipment degradation indication due to ageing, etc.

Nuclear plant operators are achieving high availability through integrated programmes, where international co-operation is playing a key role. The IAEA activities, which include nuclear power plant performance assessment and feedback, outage optimisation, 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 its role in maximising the safety and reliability of the operation of nuclear plants by exchanging information and encouraging communication of experience.

Technological maturity, economic competitiveness and financing arrangements for new plants are key factors in decision making. Continued vigilance in nuclear power plant operation, and enhancement of safety culture and international co-operation are highly important in preserving the potential of nuclear power to contribute to future energy strategies.

## 7. CONCLUSIONS

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.

The energy availability (or unit capability factor) gives an indication of how the plant effectively operates and on its availability to the electricity grid. In a competitive environment, the plant becomes economically viable only if it is reliable and safe, and provides electricity to the grid at low costs. A plant produces revenues when it generates and deliveries electricity to the grid. Therefore, key factors influencing plant performance should be analysed to identify and solve problem areas considering cost-benefit analysis of any activity/programme before 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.

For fossil-fuel units the lesson learnt through this survey, which covers some 45 countries, are consistent with those presented in the 1998 report. For the period 1997-1999, they reveal a further 1.2% improvement in plant availability (steam turbines compared with the period 1994-1996). This improvement is due to a reduction in planned unavailability (from 11.8 % to 10.6 %).

Over the last 10 years, fossil fuel plants earned 4% on Energy Availability Factor, representing 2.1% gain on unplanned unavailability, and 1.9% gain on planned unavailability. This clearly demonstrates a better usage of planned outages (duration, content, frequency, etc.), while preventive maintenance performed appears to be increasingly better adapted to real needs and quality of equipment in operation.

Furthermore, for fossil-fired units, the differences between regions around the world concerning both installation size and fuel types used are no longer pertinent from a statistical viewpoint, as was underscored at previous Congresses. Clearly, a more sophisticated statistical analysis would mean taking into account more specific factors, enabling uniform installation "families" to be defined.

For gas turbines and combined cycle units, this report presents the results of the data collection efforts over the last three-years, where the participating countries have expanded from ten countries in 1998 to sixteen countries in 2001 and the total data set has grown significantly. The average cumulative energy availability factor for gas turbine is 83.5% while planned energy availability factors is 7.28%. Combined cycle plants also present the same order of energy availability factor (85%) and a little higher planned energy unavailability factor, 11%. These results are of same order as for the fossil-fired units.

The worldwide operating nuclear power plants (438 in total) presented average energy availability factor of 81% in 1999 and 82% in 2000, the three years average for the period

1997-1999 was 79.6%. These results are also consistent with the previous report, which covered the period 1994-1996. The worldwide planned unavailability factor was 13.9%. This represents an improvement of about 5% in comparison with the value of 16.1% for the period 1994-1996. The unplanned unavailability factor also decreased from 7% in 1994-1996 to 6.5% in 1997-1999.

In terms of energy availability, the performance of the worldwide nuclear power plants has been steadily improving over the last several years. World nuclear power plants have achieved high performance standard, the average availability has increased significantly, and in many countries, longer refuelling cycles were implemented and significant reductions in the duration of refuelling outages, number of scrams and number of significant events were achieved. All these are positive aspects, which play a role when assessing the future of the current operating nuclear power plants in the competitive environment and on planning additional capacity to the electricity grids.

De-regulation and privatization are almost worldwide phenomena. The competitive environment has significant implications for plant operations, including among others, the need for efficient use of resources; effective management of plant activities such as outages and on-line maintenance; sharing of resources and greater use of analytical tools to balance costs and related benefits of proposed activities.

## **8. LIST OF COUNTRIES PROVIDING INFORMATION ON FOSSIL THERMAL GENERATING UNITS AND NUCLEAR POWER TO IAEA-PRIS FOR THE PURPOSES OF THE PRESENT PAPER**

### **Fossil-fired Thermal Generating Units**

Algeria – Argentina – Australia – Austria – Belgium – Brazil – Canada – China – Croatia – Czech Rep. – Croatia - Denmark – Ecuador – Egypt – Finland – France – Germany – Hong Kong (China) - Hungary – Indonesia – Iran Islamic Rep. – Ireland – Israel – Italy – Japan – Jordan – Korea Rep. – Latvia – Mexico – Morocco – Netherlands – New Zealand – Pakistan – Poland – Portugal – Romania – Russian Federation – Slovenia – South Africa – Spain – Syrian Arab Republic – Saudi Arabia - Switzerland – Thailand – Taiwan – Turkey – Ukraine – United States of America – Venezuela.

For various reasons, although some countries provided information, it was not (or only partially) taken into account for the purposes of the present paper.

### **Nuclear Power Plants**

Argentina - Armenia - Belgium - Brazil - Bulgaria - Canada - China - Czech Republic - Finland - France - Germany - Hungary - India - Italy - Japan - Kazakhstan - Korea, Rep. - Lithuania - Mexico - Netherlands - Pakistan - Romania - Russian Federation - Slovakia - Slovenia - South Africa - Spain - Sweden - Switzerland - Ukraine - United Kingdom - United States of America.

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- [7] Exchange of Availability/Performance Data on Gas Turbine and Combined Cycle Generating Plant, 15<sup>th</sup> WEC Congress, 1992.

**APPENDIX C – FOSSIL-FUEL THERMAL GENERATING UNITS**

Annual Unavailability of Steam Turbine Units (1997 – 1999, annual tables)

- C1 Fossil Fuels, World\*, 100 to > 1000 MW
- C2 Solid Fuels, World\*, 100 to > 1000 MW
- C3 Liquid and Gaseous Fuels, World\*, 100 to > 1000 MW
- C4 Fossil Fuels, North America, 100 to > 1000 MW
- C5 Solid Fuels, North America, 100 to > 1000 MW
- C6 Liquid and Gaseous Fuels, North America, 100 to > 1000 MW
- C7 Fossil Fuels, Western Europe, 100 to > 1000 MW
- C8 Solid Fuels, Western Europe 100 to > 1000 MW
- C9 Liquid and Gaseous Fuels, Western Europe, 100 to > 1000 MW
- C10 Fossil Fuels, Other Countries, 100 to > 1000 MW
- C11 Solid Fuels, Other countries, 100 to > 1000 MW
- C12 Liquid and Gaseous Fuels, Other Countries, 100 to > 1000 MW
- C13 Fossil Fuels, Japan, 100 to > 1000 MW
- C14 Solid Fuels, Japan, 100 to > 1000 MW
- C15 Liquid and Gaseous Fuels, Japan, 100 to > 1000 MW
- C16 Fossil Fuels, China, 100 to > 1000 MW
- C17 Fossil Fuels, Russian Federation, 100 to > 1000 MW

Energy Availability of Fossil-fired Units (diagonal tables)

- C18 Fossil Fuels, World\*, Steam turbine, 100 to > 1000 MW
- C19 Fossil Fuels, North America, Steam Turbine, 100 to > 1000 MW
- C20 Fossil Fuels, Western Europe, Steam turbine, 100 to > 1000 MW
- C21 Fossil Fuels, Other countries, Steam turbine, 100 to > 1000 MW
- C22 Fossil Fuels, Japan, Steam turbine, 100 to > 1000 MW

**APPENDIX G – GAS TURBINE AND COMBINED CYCLE UNITS**

Three Years Average Availability Factors (Tables)

- Table G1. Availability Statistics for Gas Turbine Plant 1991 - 1993
- Table G2. Availability Statistics for Gas Turbine Plant 1994 - 1996
- Table G3. Availability Statistics for Combined Cycle Plant 1991 - 1993
- Table G4. Availability Statistics for Combined Cycle Plant 1994 - 1996

**APPENDIX N – NUCLEAR POWER PLANTS STATUS, TRENDS AND AVAILABILITY AND UNAVAILABILITY**

- N1 - Status of nuclear power plants worldwide (as of 31 December 2000)
- N2 - Number of Power Plants by Reactor Type and Region (as of 31 December 2000)
- N3 - Number of Nuclear Power Plants by Age (as of 31 December 2000)
- N4 - Distribution of Nuclear Power Plants by Age and Type (as of 31 December 2000)
- N5 - Distribution of Nuclear Power Plants by Age and Region (as of 31 December 2000)
- N6 - Nuclear Share of Electricity Generation in 2000 (%)
- N7 - Annual World Energy Availability and Unavailability Factors
- N8 - Energy Availability and Unavailability Factors – PWR
- N9 - Energy Availability and Unavailability Factors – BWR
- N10 - Energy Availability and Unavailability Factors – PHWR
- N11 - Energy Availability and Unavailability Factors – WWER
- N12 - Energy Availability and Unavailability Factors – LWGR
- N13 - Energy Availability and Unavailability Factors by Age
- N14 - Energy Availability and Unavailability Factors by Region – North America
- N15 - Energy Availability and Unavailability Factors by Region – Western Europe
- N16 - Energy Availability and Unavailability Factors by Region – Eastern Europe
- N17 - Energy Availability and Unavailability Factors by Region – Far East
- N18 - Energy Availability and Unavailability Factors by Region – Middle East and South Asia
- N19 - Energy Availability and Unavailability Factors by Region – Latin America
- N20 - Energy Availability and Unavailability Factors by Region – Africa

**ANNEX 1 – EURELECTRIC “THERPERF” NETWORK OF EXPERTS, STATISTICAL DATA ON THE PERFORMANCE OF FOSSIL-FUELLED POWER PLANTS****ANNEX 2 – GENERATING AVAILABILITY DATA SYSTEMS (GADS) OF THE NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL**

APPENDIX C1 - FOSSIL FUELS, WORLD, 100 TO > 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

**World\* (-CN, -JP, -RU)  
100 to > 1000 MW  
Fossil fuels**

AA0410CYY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	89933	81991	77632	83185
	nb	653	594	563	603
	PUF	10.1	9.5	10.7	10.1
	UUF	5.1	5.6	5.7	5.4
	EAF	84.8	84.9	83.6	84.5
<b>200 to 299 MW</b>	MW	90266	84604	80345	85072
	nb	391	368	352	370
	PUF	11.3	12.0	12.4	11.9
	UUF	5.4	5.7	6.6	5.9
	EAF	83.3	82.3	81.0	82.2
<b>300 to 399 MW</b>	MW	115328	100922	96266	104172
	nb	348	304	290	314
	PUF	10.5	10.8	11.7	11.0
	UUF	6.4	6.6	5.8	6.3
	EAF	83.1	82.6	82.5	82.7
<b>400 to 599 MW</b>	MW	181230	169365	165182	171926
	nb	358	334	325	339
	PUF	10.0	9.9	11.0	10.3
	UUF	6.0	5.8	6.1	6.0
	EAF	84.0	84.3	82.9	83.7
<b>600 to 799 MW</b>	MW	116275	103659	99950	106628
	nb	171	152	147	157
	PUF	9.3	11.2	10.2	10.2
	UUF	5.8	5.9	5.7	5.8
	EAF	84.9	82.9	84.1	84.0
<b>800 to 999 MW</b>	MW	28186	28244	28315	28248
	nb	34	34	34	34
	PUF	8.4	9.4	12.9	10.2
	UUF	4.0	4.4	3.9	4.1
	EAF	87.6	86.2	83.2	85.7
<b>&gt; 1000 MW</b>	MW	15828	15780	15828	15812
	nb	13	13	13	13
	PUF	7.7	12.6	11.7	10.6
	UUF	7.4	8.0	11.6	9.0
	EAF	84.9	79.4	76.7	80.4
<b>100 to &gt; 1000 MW</b>	MW	637046	584565	563518	595043
	nb	1968	1799	1724	1830
	PUF	10.0	10.6	11.3	10.6
	UUF	5.8	5.9	6.0	5.9
	EAF	84.2	83.5	82.7	83.5

\*List of countries : Argentina + Austria + Belgium + Switzerland + Czech Rep. + Germany + Denmark + Egypt + Spain + France + China (HK) + Croatia + Hungary + Indonesia + Ireland + Israel + Italy + Jordan + Mexico + Netherlands + New Zealand + Pakistan + Poland + Portugal + Romania + Slovenia + Syrian Arab Rep. + Thailand + Taiwan + United States + Canada + Venezuela + South Africa

## APPENDIX C2 - SOLID FUELS, WORLD, 100 TO &gt; 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

**World\* (-CN, -JP, -RU)  
100 to > 1000 MW  
Solid fuels**

AA1510CYY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	51280	43736	43058	46025
	nb	374	319	313	335
	PUF	9.4	8.9	10.3	9.5
	UUF	4.9	4.8	5.5	5.1
	EAF	85.7	86.3	84.2	85.4
<b>200 to 299 MW</b>	MW	59599	54603	53652	55951
	nb	262	242	239	248
	PUF	11.1	11.7	11.7	11.5
	UUF	4.8	4.8	5.8	5.1
	EAF	84.1	83.5	82.5	83.4
<b>300 to 399 MW</b>	MW	62083	52571	52720	55791
	nb	188	159	160	169
	PUF	9.4	9.6	11.0	10.0
	UUF	6.2	5.9	5.7	6.0
	EAF	84.4	84.5	83.3	84.0
<b>400 to 599 MW</b>	MW	131034	121415	118975	123808
	nb	256	236	231	241
	PUF	9.7	9.5	10.4	9.8
	UUF	6.0	6.1	6.1	6.1
	EAF	84.3	84.4	83.5	84.1
<b>600 to 799 MW</b>	MW	87771	77154	77959	80961
	nb	130	114	115	120
	PUF	8.4	8.2	9.5	8.7
	UUF	6.0	6.4	5.4	5.9
	EAF	85.6	85.4	85.1	85.4
<b>800 to 999 MW</b>	MW	21730	20925	20975	21210
	nb	26	25	25	25
	PUF	8.6	9.0	10.4	9.3
	UUF	4.4	4.7	4.5	4.5
	EAF	87.0	86.3	85.1	86.2
<b>&gt; 1000 MW</b>	MW	14856	14808	14856	14840
	nb	12	12	12	12
	PUF	7.0	12.2	12.4	10.5
	UUF	6.8	6.7	7.5	7.0
	EAF	86.2	81.1	80.1	82.5
<b>100 to &gt; 1000 MW</b>	MW	428353	385212	382195	398587
	nb	1248	1107	1095	1150
	PUF	9.4	9.6	10.5	9.8
	UUF	5.7	5.8	5.8	5.7
	EAF	84.9	84.6	83.7	84.5

\*List of countries : Austria + Belgium + Czech Rep. + Germany + Denmark + Spain + France + China (HK) + Croatia + Hungary + Indonesia + Ireland + Italy + Mexico + Netherlands + Poland + Portugal + Romania + Slovenia + Thailand + Taiwan + United States + Canada + South Africa

## APPENDIX C3 - LIQUID AND GASEOUS FUELS, WORLD, 100 TO &gt; 1000 MW

ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)World\* (-CN, -JP, -RU)  
100 to > 1000 MW  
Liquid and gaseous fuels

AA1810CYY		1997	1998	1999	Average
100 to 199 MW	MW	36613	36215	32534	35121
	nb	264	260	235	253
	PUF	11.3	10.4	11.1	10.9
	UUF	5.2	6.2	5.5	5.6
	EAF	83.5	83.4	83.4	83.5
200 to 299 MW	MW	28907	28241	24933	27360
	nb	121	118	105	115
	PUF	11.6	12.4	13.8	12.5
	UUF	6.9	7.3	8.4	7.5
	EAF	81.5	80.3	77.8	80.0
300 to 399 MW	MW	48085	43191	38386	43221
	nb	144	129	114	129
	PUF	11.9	12.3	13.0	12.3
	UUF	7.1	7.8	6.4	7.1
	EAF	81.0	79.9	80.6	80.6
400 to 599 MW	MW	47896	45650	43907	45818
	nb	98	94	90	94
	PUF	10.9	11.2	12.7	11.6
	UUF	6.2	5.3	6.2	5.9
	EAF	82.9	83.5	81.1	82.5
600 to 799 MW	MW	28504	26505	21991	25667
	nb	41	38	32	37
	PUF	12.4	20.1	12.7	15.1
	UUF	5.1	4.3	6.8	5.3
	EAF	82.5	75.6	80.5	79.6
800 to 999 MW	MW	6456	7319	7340	7038
	nb	8	9	9	9
	PUF	7.4	10.5	20.0	12.8
	UUF	2.9	3.5	2.1	2.8
	EAF	89.7	86.0	77.9	84.4
> 1000 MW	MW	972	972	972	972
	nb	1	1	1	1
	PUF	18.0	18.0	1.1	12.4
	UUF	15.8	27.0	74.7	39.2
	EAF	66.2	55.0	24.2	48.4
100 to > 1000 MW	MW	197433	188093	170063	185196
	nb	677	649	586	637
	PUF	11.4	12.7	12.9	12.3
	UUF	6.1	6.3	6.7	6.3
	EAF	82.5	81.0	80.4	81.4

\*List of countries : Argentina + Austria + Belgium + Switzerland + Germany + Denmark + Spain + France + Croatia + Hungary + Indonesia + Ireland + Italy + Jordan + Mexico + Netherlands + New Zealand + Pakistan + Portugal + Romania + Syrian Arab Rep. + Thailand + Taiwan + United States + Canada + Venezuela

APPENDIX C4 - FOSSIL FUELS, NORTH AMERICA, 100 TO > 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

<b>North America*</b> <b>100 to &gt; 1000 MW</b> <b>Fossil fuels</b>
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AA0110YY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	54782	54277	51928	53662
	nb	398	395	380	391
	PUF	10.3	9.9	10.6	10.2
	UUF	4.9	5.3	5.4	5.2
	EAF	84.8	84.8	84.0	84.6
<b>200 to 299 MW</b>	MW	37785	37366	35554	36902
	nb	164	162	154	160
	PUF	9.8	10.0	11.6	10.4
	UUF	5.4	5.7	5.4	5.5
	EAF	84.8	84.3	83.0	84.1
<b>300 to 399 MW</b>	MW	48820	47144	43369	46444
	nb	144	139	128	137
	PUF	11.6	11.3	12.3	11.7
	UUF	6.6	6.8	5.8	6.4
	EAF	81.8	81.9	81.9	81.9
<b>400 to 599 MW</b>	MW	126467	124345	119577	123463
	nb	253	249	239	247
	PUF	11.1	11.0	12.0	11.4
	UUF	7.1	6.7	6.6	6.8
	EAF	81.8	82.3	81.4	81.8
<b>600 to 799 MW</b>	MW	81406	81529	77208	80048
	nb	117	117	111	115
	PUF	8.5	10.3	11.0	9.9
	UUF	6.0	6.7	6.6	6.4
	EAF	85.5	83.0	82.4	83.7
<b>800 to 999 MW</b>	MW	27306	28244	28315	27955
	nb	33	34	34	34
	PUF	8.6	9.4	12.9	10.3
	UUF	3.9	4.4	3.9	4.1
	EAF	87.5	86.2	83.2	85.6
<b>&gt; 1000 MW</b>	MW	15828	15780	15828	15812
	nb	13	13	13	13
	PUF	7.7	12.6	11.7	10.6
	UUF	7.4	8.0	11.6	9.0
	EAF	84.9	79.4	76.7	80.4
<b>100 to &gt; 1000 MW</b>	MW	392394	388685	371779	384286
	nb	1122	1109	1059	1097
	PUF	10.1	10.6	11.6	10.8
	UUF	6.1	6.3	6.2	6.2
	EAF	83.8	83.1	82.2	83.0

\*List of countries : United States + Canada

APPENDIX C5 - SOLID FUELS, NORTH AMERICA, 100 TO > 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

**North America\*  
100 to > 1000 MW  
Solid fuels**

AA2110YY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	33194	33057	33211	33154
	nb	242	241	242	242
	PUF	9.6	9.3	9.9	9.6
	UUF	5.2	5.6	5.9	5.5
	EAF	85.2	85.1	84.2	84.9
<b>200 to 299 MW</b>	MW	26546	26104	26088	26246
	nb	116	114	114	115
	PUF	9.3	9.0	11.1	9.8
	UUF	5.6	6.0	5.3	5.7
	EAF	85.1	85.0	83.6	84.5
<b>300 to 399 MW</b>	MW	28623	28380	27880	28294
	nb	87	86	85	86
	PUF	10.2	10.1	11.4	10.6
	UUF	7.2	7.1	6.2	6.8
	EAF	82.6	82.8	82.4	82.6
<b>400 to 599 MW</b>	MW	89017	88097	85657	87590
	nb	176	174	169	173
	PUF	11.0	10.5	11.1	10.9
	UUF	7.2	7.0	6.9	7.0
	EAF	81.8	82.5	82.0	82.1
<b>600 to 799 MW</b>	MW	63216	64050	64243	63836
	nb	92	93	93	93
	PUF	8.5	8.4	10.1	9.0
	UUF	6.2	7.2	6.3	6.6
	EAF	85.3	84.4	83.6	84.4
<b>800 to 999 MW</b>	MW	20850	20925	20975	20917
	nb	25	25	25	25
	PUF	9.0	9.0	10.4	9.5
	UUF	4.2	4.7	4.5	4.5
	EAF	86.8	86.3	85.1	86.0
<b>&gt; 1000 MW</b>	MW	14856	14808	14856	14840
	nb	12	12	12	12
	PUF	7.0	12.2	12.4	10.5
	UUF	6.8	6.7	7.5	7.0
	EAF	86.2	81.1	80.1	82.5
<b>100 to &gt; 1000 MW</b>	MW	276302	275421	272910	274878
	nb	750	745	740	745
	PUF	9.6	9.7	10.8	10.0
	UUF	6.3	6.6	6.3	6.4
	EAF	84.1	83.7	82.9	83.6

\*List of countries : United States + Canada

APPENDIX C6 - LIQUID AND GASEOUS FUELS, NORTH AMERICA, 100 TO > 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

**North America\*  
100 to > 1000 MW  
Liquid and gaseous fuels**

AA2410YY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	21588	21220	18717	20508
	nb	156	154	138	149
	PUF	11.3	10.7	11.8	11.3
	UUF	4.4	4.9	4.6	4.6
	EAF	84.3	84.4	83.6	84.1
<b>200 to 299 MW</b>	MW	11239	11262	9466	10656
	nb	48	48	40	45
	PUF	11.0	12.3	12.8	12.0
	UUF	5.0	5.1	5.5	5.2
	EAF	84.0	82.6	81.7	82.8
<b>300 to 399 MW</b>	MW	20197	18764	15489	18150
	nb	57	53	43	51
	PUF	13.6	13.2	14.0	13.6
	UUF	5.8	6.4	5.2	5.8
	EAF	80.6	80.4	80.8	80.6
<b>400 to 599 MW</b>	MW	37450	36248	33920	35873
	nb	77	75	70	74
	PUF	11.5	12.3	14.3	12.6
	UUF	6.7	5.8	5.7	6.1
	EAF	81.8	81.9	80.0	81.3
<b>600 to 799 MW</b>	MW	18190	17479	12965	16211
	nb	25	24	18	22
	PUF	8.6	16.9	15.4	13.4
	UUF	5.6	4.5	8.2	5.9
	EAF	85.8	78.6	76.4	80.7
<b>800 to 999 MW</b>	MW	6456	7319	7340	7038
	nb	8	9	9	9
	PUF	7.4	10.5	20.0	12.8
	UUF	2.9	3.5	2.1	2.8
	EAF	89.7	86.0	77.9	84.4
<b>&gt; 1000 MW</b>	MW	972	972	972	972
	nb	1	1	1	1
	PUF	18.0	18.0	1.1	12.4
	UUF	15.8	27.0	74.7	39.2
	EAF	66.2	55.0	24.2	48.4
<b>100 to &gt; 1000 MW</b>	MW	116092	113264	98869	109408
	nb	372	364	319	352
	PUF	11.1	12.8	14.1	12.6
	UUF	5.6	5.5	6.1	5.7
	EAF	83.3	81.7	79.8	81.7

\*List of countries : United States + Canada

APPENDIX C7 - FOSSIL FUELS, WESTERN EUROPE, 100 TO > 1000 MW

**ANNUAL UNAVAILABILITY  
OF STEAM TURBINE UNITS  
MORE THAN  
ONE YEAR OLD (%)**

**Western Europe\*  
100 to > 1000 MW  
Fossil fuels**

AA0210YY		1997	1998	1999	Average
<b>100 to 199 MW</b>	MW	17100	9387	7621	11369
	nb	126	70	56	84
	PUF	9.2	7.2	9.4	8.7
	UUF	4.9	3.5	5.4	4.6
	EAF	85.9	89.3	85.2	86.7
<b>200 to 299 MW</b>	MW	20551	15991	12699	16414
	nb	79	61	49	63
	PUF	8.1	11.1	7.8	9.0
	UUF	4.6	4.8	7.2	5.3
	EAF	87.3	84.1	85.0	85.7
<b>300 to 399 MW</b>	MW	30108	17048	15837	20998
	nb	94	54	50	66
	PUF	9.4	11.6	11.8	10.6
	UUF	4.5	3.2	2.1	3.6
	EAF	86.1	85.2	86.1	85.8
<b>400 to 599 MW</b>	MW	19951	9658	10243	13284
	nb	39	18	19	25
	PUF	7.6	5.5	6.1	6.7
	UUF	3.6	4.4	9.2	5.2
	EAF	88.8	90.1	84.7	88.1
<b>600 to 799 MW</b>	MW	21777	7826	7826	12476
	nb	33	12	12	19
	PUF	15.4	29.2	9.6	17.1
	UUF	5.2	4.3	5.1	5.0
	EAF	79.4	66.5	85.3	77.9
<b>100 to &gt; 1000 MW</b>	MW	110367	59910	54226	74834
	nb	372	215	186	258
	PUF	9.9	12.1	9.2	10.3
	UUF	4.6	4.0	5.6	4.7
	EAF	85.5	83.9	85.2	85.0

\*List of countries : Austria + Belgium + Switzerland + Germany + Denmark + Spain + France + Ireland + Italy + Netherlands + Portugal