# The Nexus Between Safety and Operational Performance in the U.S. Nuclear Industry

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## Executive Summary

The U.S. nuclear power industry has consistently improved performance over the past 20 years. This performance manifests itself in many dimensions, including worker safety, public safety and plant reliability.

There are many factors influencing this improvement including the cultivation of a strong safety and reliability culture by utilities, a strong independent nuclear regulator in the U.S. Nuclear Regulatory Commission (NRC), an independent industry excellence organization in the Institute of Nuclear Power Operators (INPO), and the NRC's adoption of a risk-informed safety focus. Over the past 20 years, improving plant performance has been coupled with the enhanced safety focus provided by a risk-informed approach that focuses resources on the most safety significant issues. Today, the U.S. nuclear industry is performing at the highest levels of safety and reliability in the world.

NEI has collected all the relevant individual and aggregate performance indicators available from public sources, including NRC and INPO, spanning the past several decades. The purpose of this report is to illuminate the performance improvements achieved and demonstrate the connection between this improved performance and safety.

The unequivocal picture provided by these performance indicators includes the following:

- **U.S. Industry Performance at All Time Highs**
  Industry overall performance has dramatically improved over the past 20 years, continuing a trend started in the 1980s. This performance trend is so significant that, over the past 20 years, every INPO and NRC performance indicator has improved.

- **Industry Performance Levels Improve Safety**
  The breadth of improved industry performance has directly led to improved safety and has reduced risk. Performance improvements have translated to enhancements in worker safety and nuclear safety. NRC risk models show that reduced challenges and improved equipment reliability have reduced risk levels by a factor of 3 to 7 for a spectrum of representative plants, based on NRC's own data.

- **Risk-informed Focus Improves Safety**
  The safety focus enabled by the NRC's establishment and support of a risk-informed framework and industry's adoption of risk-informed approaches over the last 25 years has further improved safety. A broad spectrum of risk-informed approaches has been shown to improve safety and improve operational focus.

The nexus between performance and safety has not always been understood. This report assembles objective data to demonstrate this nexus between industry performance and safety and describes how a risk-informed safety focus further improves plant safety.

 

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# 1 INTRODUCTION

The focus of this report is the nexus between industry performance and plant safety. In this document, “performance” includes both operational and safety aspects and is an outcome of numerous elements such as the reliability of equipment, the reduction in challenges to plant operations, the protection of workers, and the proficiency of operations. These elements are inextricably linked to each other and to the safety of each facility. In short, a well-run plant is a safe plant for the workers and the public, and a well-run plant is an efficient plant. Byproducts of high performance include improved regulatory performance, worker safety, plant reliability, and public health and safety.

A fundamental tenet of U.S. nuclear regulation is that the licensees (utility owner-operators) are responsible for safety. The U.S. nuclear power industry takes this responsibility seriously and safe operations is and will always be the number one priority. Over 40 years ago, the industry CEOs established the Institute of Nuclear Power Operations (INPO) to independently drive the industry to higher and higher levels of excellence. The INPO model includes a level of accountability to the achievement of excellence not present in any other industry in the world.

The U.S. Nuclear Regulatory Commission (NRC), as an independent regulatory authority, has also played an important role in ensuring the safety of the fleet. The NRC has a long history of evolving their regulatory programs to enhance safety. Many of these programs (e.g., Maintenance Rule, Reactor Oversight Process, piping inspections, fire protection) have adopted a “risk-informed” approach to identifying and focusing on what is most important to safety. An effective risk-informed safety focus puts emphasis on items of most safety significance. This approach further improves safety by avoiding diversion of resources to items of low significance.

# 2 40 YEARS OF PERFORMANCE IMPROVEMENT

To help evaluate the nexus between industry performance and safety, all the relevant publicly available individual and aggregate performance indicators were collected from both INPO and the NRC and analyzed holistically. The data demonstrate that the U.S. nuclear power industry has a long history of performance improvement, spanning nearly 40 years.

## 2.1 Industry Performance Improvements (1980-2000)

In 2000, the U.S. nuclear industry marked the completion of two decades of performance improvement and celebrated its highest levels of safety and reliability. The NRC documented the improved safety performance of the industry through its Performance Indicator Program.[1] This program covered eight indicators (automatic scrams while critical, safety system actuations, significant events, safety system failures, forced outage rate, equipment forced outages per 1000 commercial critical hours, collective radiation exposure, and cause codes) and was used in conjunction with other tools, such as the results of routine and special inspections and the systematic assessment of licensee performance (SALP) program, for providing input to NRC management decisions regarding the need to adjust plant-specific regulatory programs.

[1] NUREG-1187, Volume 3, Performance Indicators for Operating Commercial Nuclear Power Reactors

The strong performance of the industry was remarked on by both the NRC and INPO. In her speech before the 1997 Regulatory Information Conference, then Chairman Shirley Jackson, stated:

> *The NRC evaluates the overall U.S. nuclear power reactor safety performance through a variety of mechanisms, including the use of performance indicators that, when viewed as a whole, provide additional data for determining performance trends. As measured by these indicators, the U.S. nuclear industry's safety performance has shown continuing improvement over the past 12 years.*

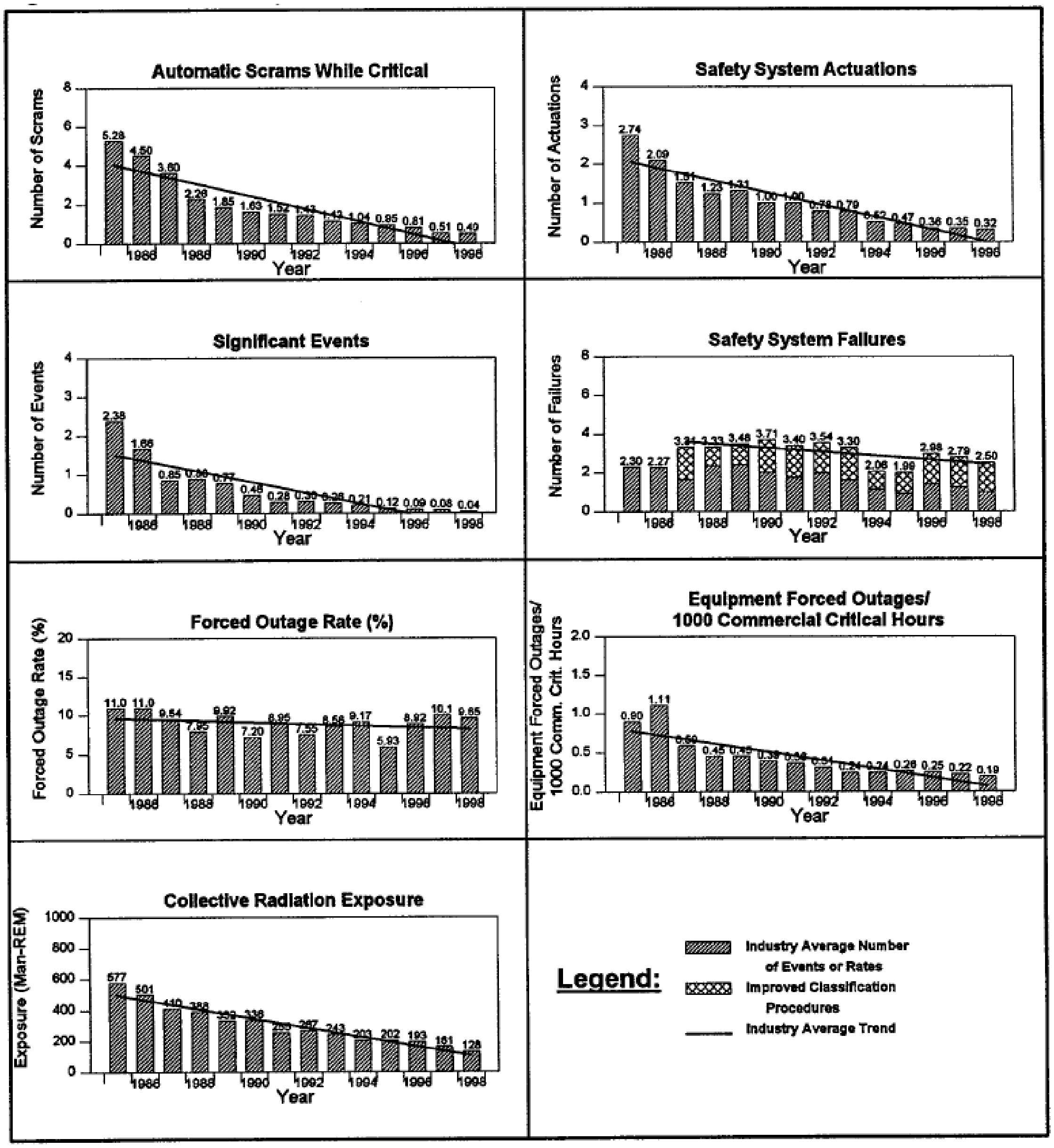
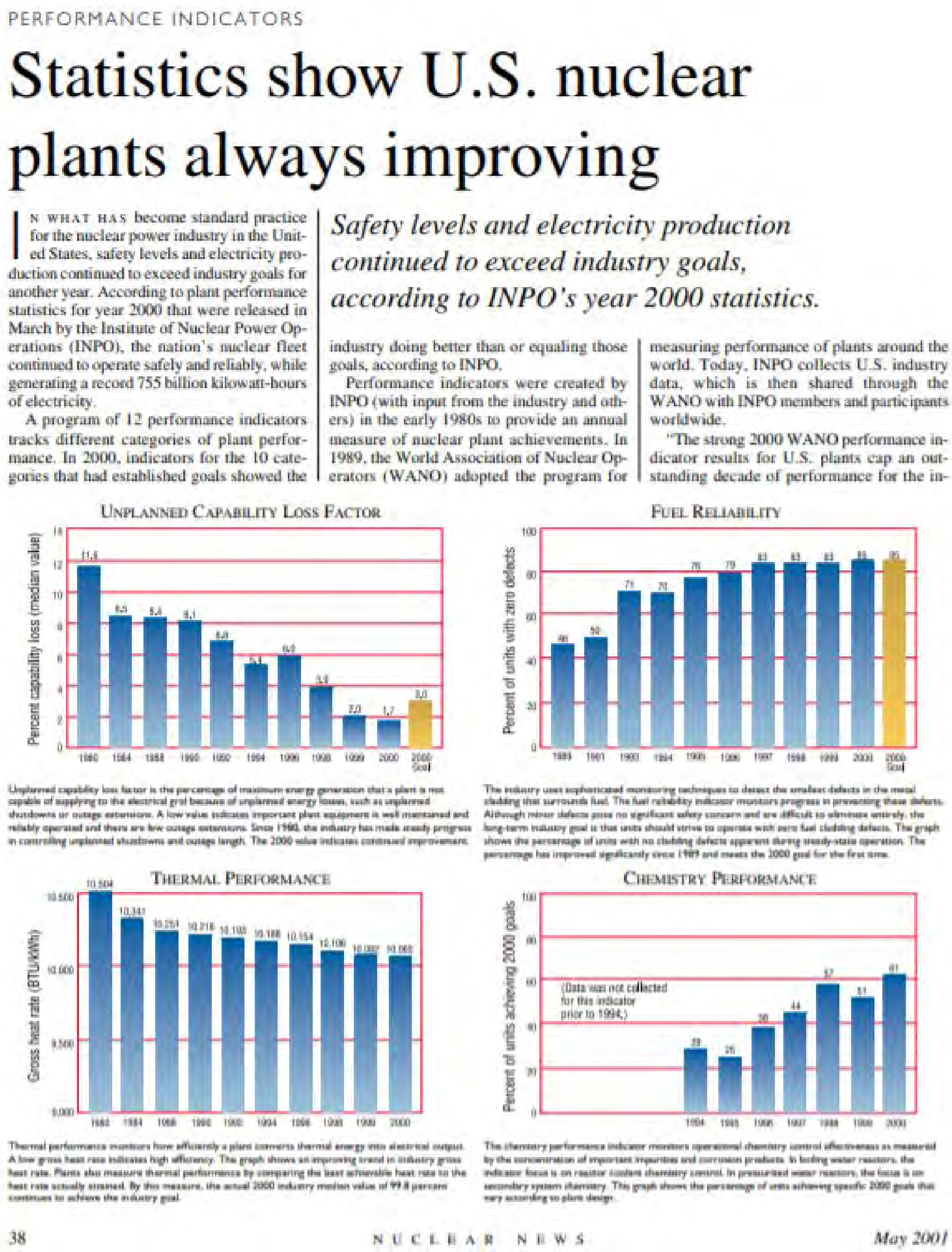



***Figure 1 - NUREG-1187, Performance Indicators for Operating Commercial Nuclear Power Plants***

In a May 2001 article[2] in *Nuclear News* (Figure 2), INPO Executive Vice President, Alfred Tollison indicated that, "The strong 2000 WANO performance indicator results for U.S. plants cap an outstanding decade of performance for the industry." The article shows U.S. industry performance against 12 performance indicators for the period 1980 to 2000. In 2000, indicators for the 10 categories with established performance goals showed the industry equaling or exceeding those goals.



PERFORMANCE INDICATORS

# Statistics show U.S. nuclear plants always improving

*Safety levels and electricity production continued to exceed industry goals, according to INPO's year 2000 statistics.*

IN WHAT HAS become standard practice for the nuclear power industry in the United States, safety levels and electricity production continued to exceed industry goals for another year. According to plant performance statistics for year 2000 that were released in March by the Institute of Nuclear Power Operations (INPO), the nation's nuclear fleet continued to operate safely and reliably, while generating a record 755 billion kilowatt-hours of electricity.

A program of 12 performance indicators tracks different categories of plant performance. In 2000, indicators for the 10 categories that had established goals showed the industry doing better than or equaling those goals, according to INPO.

Performance indicators were created by INPO (with input from the industry and others) in the early 1980s to provide an annual measure of nuclear plant achievements. In 1989, the World Association of Nuclear Operators (WANO) adopted the program for measuring performance of plants around the world. Today, INPO collects U.S. industry data, which is then shared through the WANO with INPO members and participants worldwide.

"The strong 2000 WANO performance indicator results for U.S. plants cap an outstanding decade of performance for the in-



Unplanned capability loss factor is the percentage of maximum energy generation that a plant is not capable of supplying to the electrical grid because of unplanned energy losses, such as unplanned shutdowns or outage extensions. A low value indicates important plant equipment is well maintained and reliably operated and there are few outage extensions. Since 1980, the industry has made steady progress in controlling unplanned shutdowns and outage length. The 2000 value indicates continued improvement.

The industry uses sophisticated monitoring techniques to detect the smallest defects in the metal cladding that surrounds fuel. The fuel reliability indicator monitors progress in preventing these defects. Although minor defects pose no significant safety concern and are difficult to eliminate entirely, the long-term industry goal is that units should strive to operate with zero fuel cladding defects. The graph shows the percentage of units with no cladding defects apparent during steady-state operation. The percentage has improved significantly since 1989 and meets the 2000 goal for the first time.

Thermal performance monitors how efficiently a plant converts thermal energy into electrical output. A low gross heat rate indicates high efficiency. The graph shows an improving trend in industry gross heat rate. Plants also measure thermal performance by comparing the best achievable heat rate to the heat rate actually attained. By this measure, the actual 2000 industry median value of 99.8 percent continues to achieve the industry goal.

The chemistry performance indicator monitors operational chemistry control effectiveness as measured by the concentration of important impurities and corrosion products. In boiling water reactors, the indicator focus is on reactor coolant chemistry control. In pressurized water reactors, the focus is on secondary system chemistry. This graph shows the percentage of units achieving specific 2000 goals that vary according to plant design.

38 NUCLEAR NEWS May 2001

***Figure 2 - Nuclear News, May 2001***

[2] http://www2.ans.org/pubs/magazines/nn/docs/2001-5-2.pdf

The industry's 2000 median capability factor of 91.1 percent was the highest since INPO began collecting data and significantly improved from the 62.7 percent in 1980. For the third straight year, the median value of unplanned automatic plant shutdowns was zero, whereas in 1980, the median value of unplanned automatic scrams was 7.3.

## 2.2 Performance Improvements Continue (2000-2020)

In early 2000, the NRC instituted the new Reactor Oversight Process (ROP). In establishing the thresholds for acceptable performance, the NRC acknowledged the improvements in industry performance in the 1980s and 1990s and used performance in the 1997 to 1998 time period to establish the expected performance threshold[3] for many of the new ROP indicators.

In the two decades since 2000, industry performance has continued to improve. In his November 13, 2019 testimony before the Senate Environment and Public Works Committee, Admiral Robert Willard, President and CEO of INPO stated:

> *"By many measures, the U.S. nuclear industry is in its seventh consecutive year of improving performance. It is also by WANO standards **the highest-performing national nuclear industry in the world**."[emphasis added]*

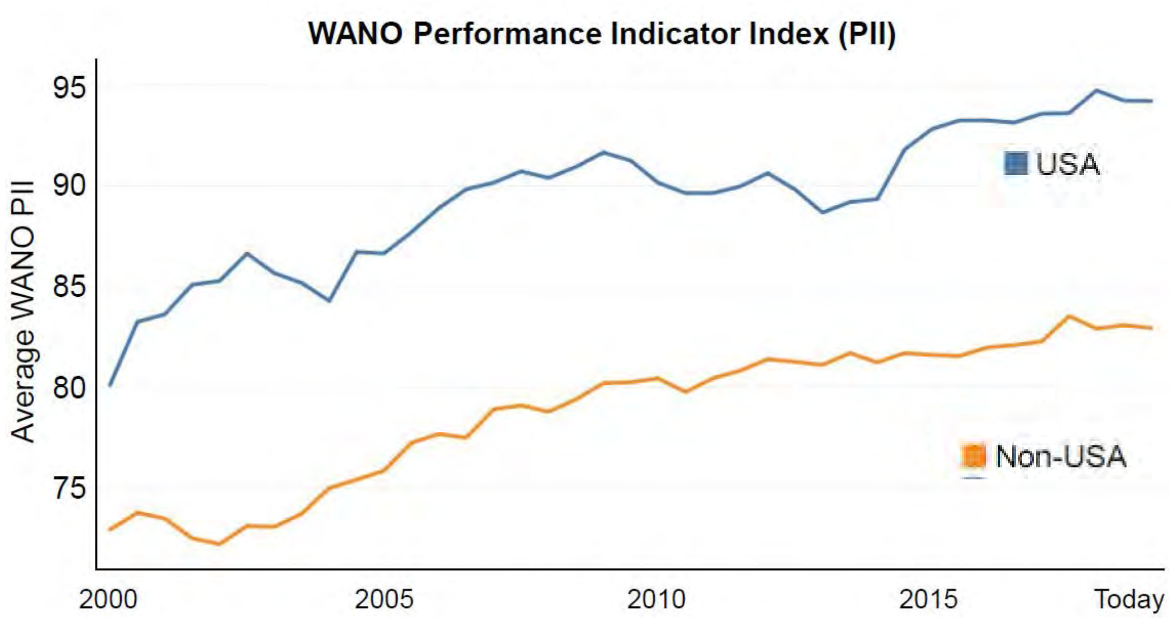



***Figure 3 - WANO Performance Indicator Index (PII)***

[3] The "Green-White" threshold establishes the transition from a region of expected performance (GREEN) to a region of performance that is outside an expected range of nominal utility performance (WHITE) but related cornerstone objectives are still being met. In establishing the Green-White threshold, the NRC used industry performance from 1997-1998 to establish expected performance by setting the threshold at a point where approximately 95% of the industry would be Green at any given time.

Pointing to a chart showing the World Association of Nuclear Operators (WANO) Performance Indicator Index for the U.S. industry compared with the rest of the world (Figure 3), Admiral Willard went on to say:

> *"[The WANO Performance Indicator Index] is actually an indicator that contains 12 areas of safety and reliability factors that are combined to yield that curve, and all have improved in the time frame … from 1990 to present. They range from capability factor … and online reliability, to safety injection and unplanned scrams, to fuel reliability, chemistry effectiveness, all the way down to industrial accident rate. [A] dozen different areas specific to safety and reliability of our nuclear reactors that have all undergone vast improvement over time to have achieved the levels of performance that the industry has achieved today."*

INPO's own performance indicator index (PII) provides insight into the breadth of industry performance improvement. The INPO performance indicator index cover a broad expanse of performance, including reactor performance, safety system performance, occupational safety, chemistry performance and radiation exposure. All of the INPO Performance Indicators (see Appendix A, Figures A1-A10) show the improvement of the U.S. nuclear industry.

Like the WANO indicator, the INPO PII shows an overall improvement in the average, but as shown in Figure 4, the INPO PII shows the broad-based improvement where the current lower quartile can be seen to exceed the performance of the median quartile in 2006.

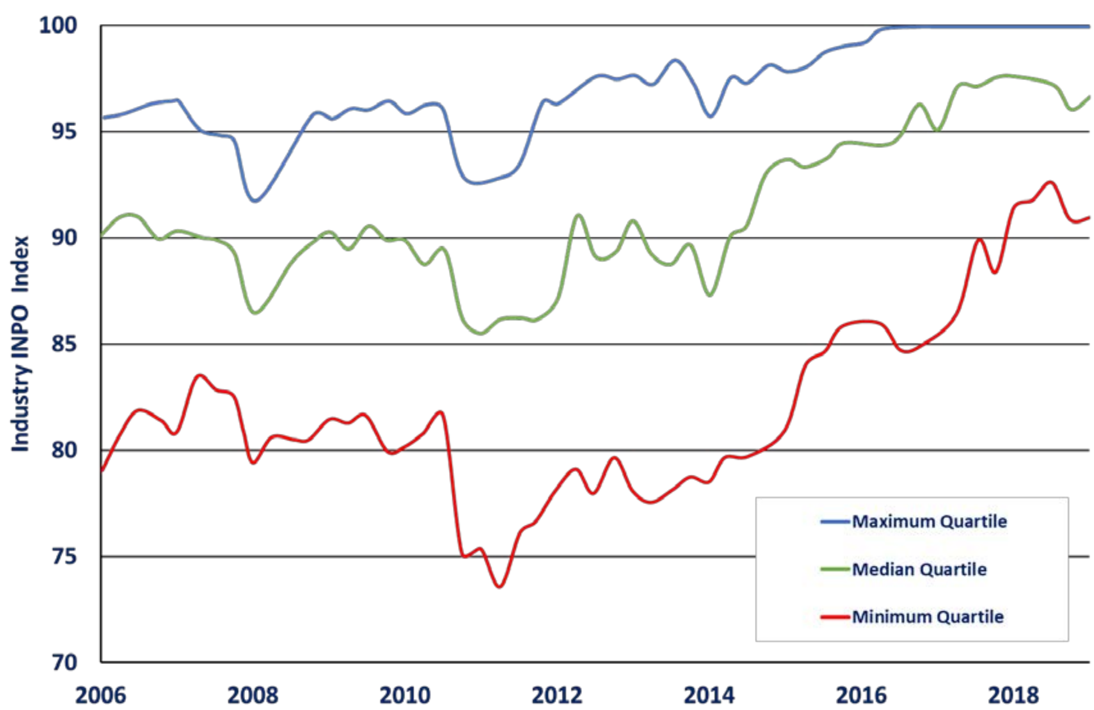



***Figure 4 – U.S. INPO Performance Indicator Index (PII)***

In its input to the INPO Convention on Nuclear Safety Report (NUREG-1650, Rev. 7), January 2019, INPO states:

> *"At the end of 2018, the U.S. nuclear industry was performing at its highest levels ever. Today, the median industry capacity factor is above 93 percent, most plants experience no automatic scrams in a year, there were no significant operational events in 2018, and collective radiation dose and industrial accident rates are both lower by a factor of seven when compared with the rates of the 1980s industry."*

### 2.3 Safety Performance as shown through NRC Reactor Oversight Process

The Reactor Oversight Process (ROP)[4] is the NRC's program to inspect, measure, and assess operating commercial nuclear power plant licensees' safety and security, and to predictably respond to declining performance. The program was implemented in 2000 with the goal of providing an objective, risk-informed, understandable, and predictable approach to nuclear power plant oversight. The then-new ROP process acknowledged the improved performance of the nuclear industry which allowed the implementation of a process that focuses more of the agency's resources on the relatively small number of plants that evidence performance problems.

The ROP uses overall performance to establish the regulatory response of the agency ranging from conducting a baseline number of hours of inspection (i.e., the baseline) for plants in Column 1 to potentially revoking a license to operate in Column 5. Columns 1 and 2 include plants that are fully meeting NRC's safety objectives, the difference being plants in Column 1 receive the baseline and plants in Column 2 receive additional inspection above the baseline to ensure robust margins to safety are being maintained. Plants in Column 3 are meeting NRC's safety objectives with a minimal reduction in margin warranting a larger number of inspection hours beyond that received in Column 2. Margin to safety is the critical figure of merit and in Columns 4 and 5 the NRC has determined that the margin has been reduced significantly or is unacceptable, respectively, and takes appropriate regulatory action. This process of increasing inspection and regulatory action as a function of declining performance is effective and has had the intended effect of addressing outlying performers well before public health and safety is impacted.

During the first year of the ROP, approximately 75% of nuclear plants were performing in a manner such that all indicators and all inspection findings were Green, placing them in Column 1 of the action matrix. Since that time, industry performance has progressively improved. In its report for the 4th quarter of 2019, the NRC shows that all performance indicators are Green, all inspection findings are Green or "No Color" and all operating nuclear plants are in Column 1 of the NRC action matrix. Figure 5 shows the percentage of operating plants in Column 1 of the NRC action matrix since the start of the ROP. This increasing trend is a clear indication of continued improvement in industry performance.

Figures B1-B17 of Appendix B provide additional detail of the trend in industry average performance indicator values since initiation of the ROP. The averages include all plants reporting for each quarter and includes plants that have subsequently shutdown. An evaluation of ROP results with and without plants that have stopped operation since the start of the ROP shows that industry averages are only minimally affected.

[4] https://www.nrc.gov/docs/ML1621/ML16214A274.pdf

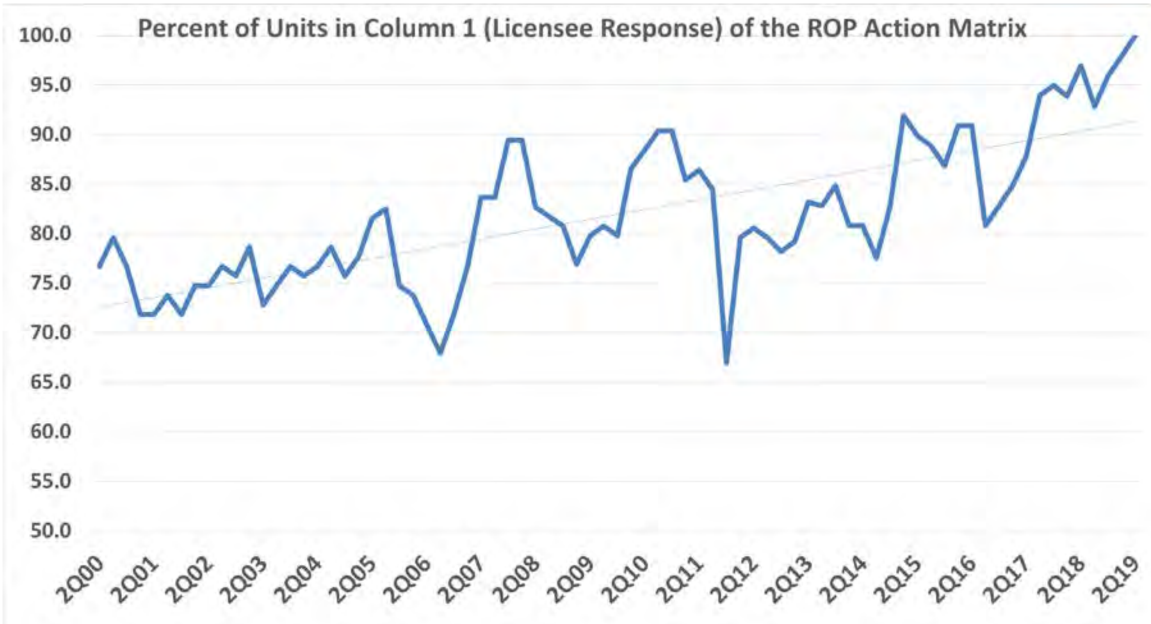



*Figure 5 - Percent of Nuclear Units in Column 1 of ROP Action Matrix*

# 3 PERFORMANCE AND SAFETY ARE INEXTRICABLY LINKED

## 3.1 Operational Performance has Improved along with Safety Performance

Up to this point, the discussion has primarily focused on improvements in industry safety performance. However, during this same period, the industry's operational performance has also improved.

One way the energy industry measures operational performance is by capacity factors. Capacity factor is the measure of how consistently a power plant runs for a specific period of time. It's expressed as a percentage and calculated by dividing the actual unit electricity output by the maximum possible output. In 2017, U.S. reactors operated at a record setting level (92.2% capacity factor). In 2018, U.S. reactors set a new record with a capacity factor of 93.4%. The average capacity factor for U.S. reactors over the last two decades has been above 90% (Figure 6). To put this into perspective, most utility scale generators operate with much lower capacity factors (Gas – 60's, Wind – 30's, Solar – 20's).

Nuclear energy facilities have annually produced about 20% of America's electricity supplies for the past two decades. Because of their electric sector-leading capacity factors, they have done so even though nuclear power plants constitute only about 10 percent of the nation's installed electric generating capacity.

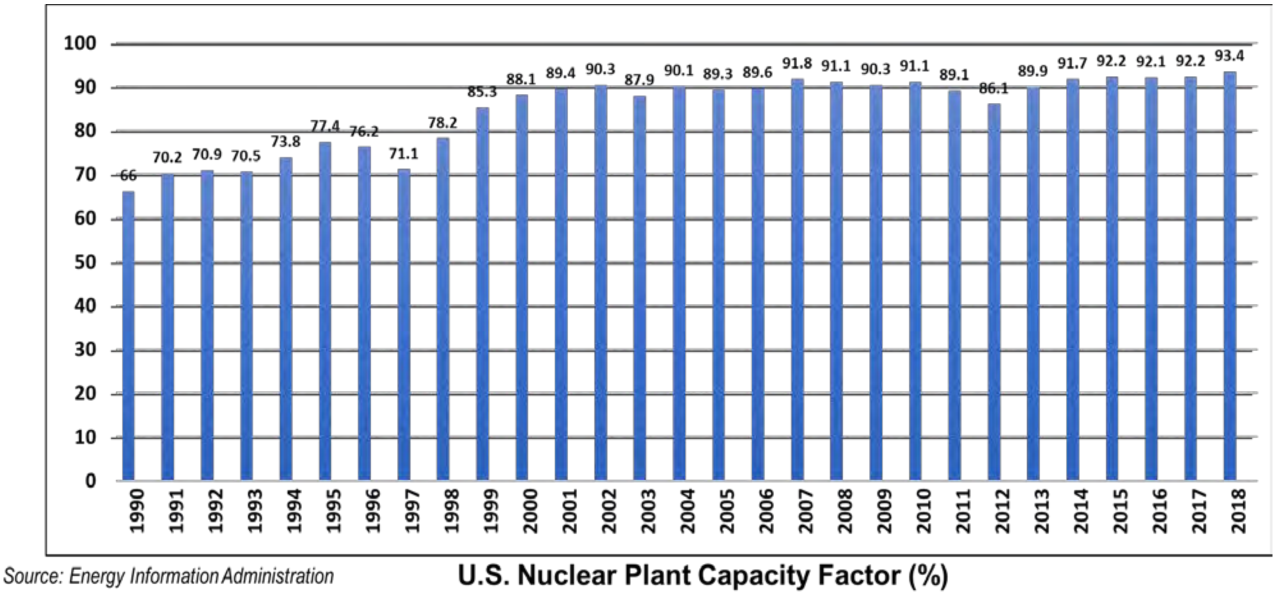



*Figure 6 - U.S. Nuclear Plant Capacity Factor (1990-2018)*

There are two key contributors to the high capacity factor demonstrated by the U.S. nuclear power industry. The first is effective management and coordination of refueling outages. Since the 1990s the average refueling outage duration has dropped by a factor of 3 (Figure 7).

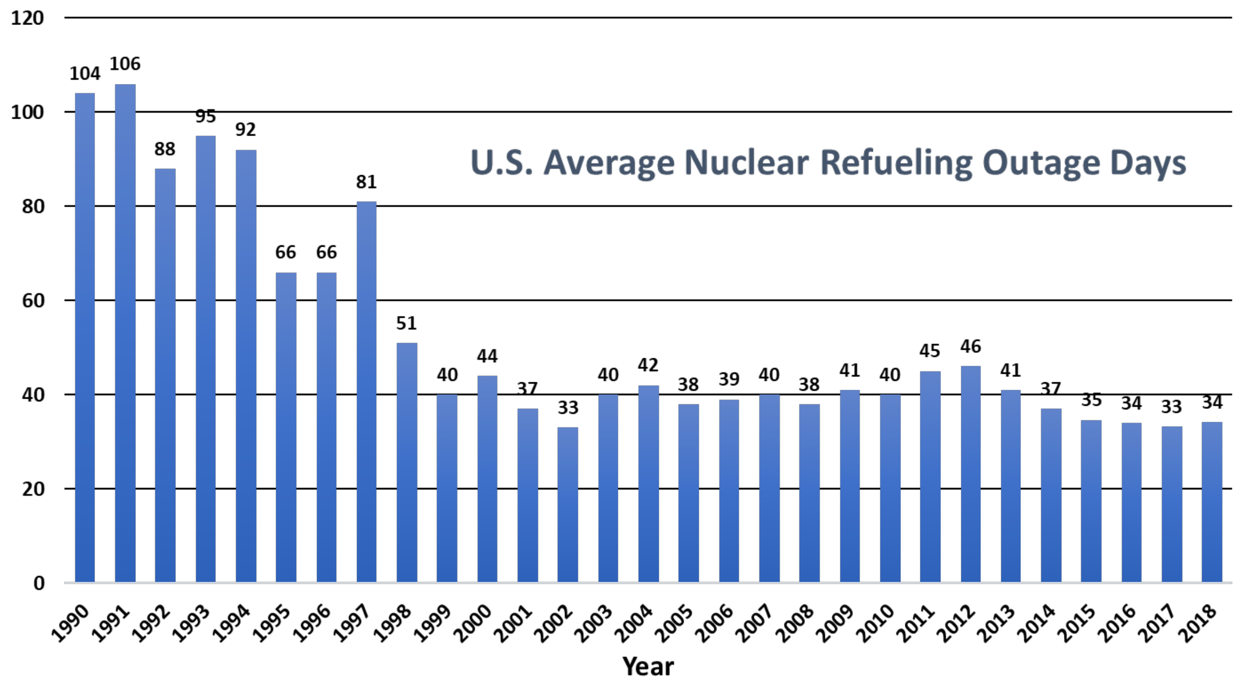



*Figure 7 - U.S. Average Nuclear Refueling Outage Days (1990-2018)*

The second key contributor is a reduction in the number of unplanned reactor trips. Since the late 1980s the number of unplanned reactor trips has fallen by a factor of 6 (Figure 8). This reduction has resulted, in part, from a more effective management of systems and equipment (INPO focus on single point vulnerabilities in plant designs).

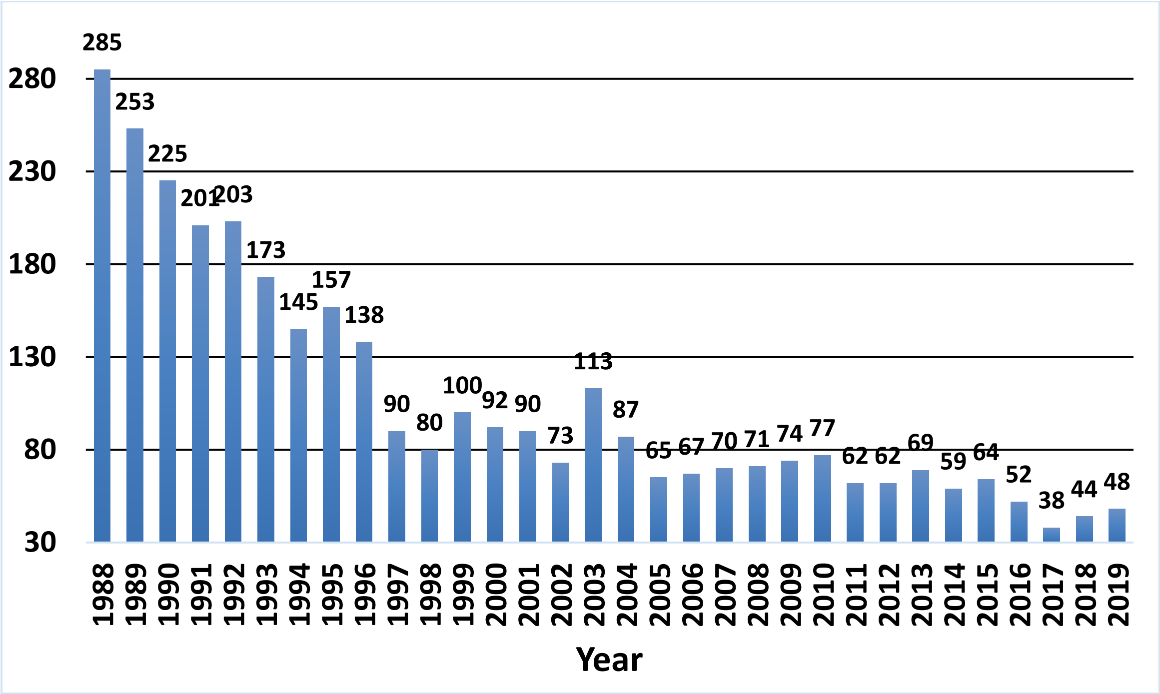



***Figure 8 - U.S. Nuclear Plant Unplanned Reactor Trips (1988-2019)***

### 3.2 Nexus Between Operational Performance and Safety Performance

The link between safety performance and operational performance should not be surprising as safety performance and operational performance are closely related. Plants, when considering modifications to equipment, processes and procedures, evaluate the impact on all aspects of operation and utilize plant probabilistic risk assessment (PRA) models to assess the impact on plant safety. Thus, when changes in processes or equipment are made that result in improvements to equipment reliability/availability, the outcome has a positive impact on both safety performance and operational performance.

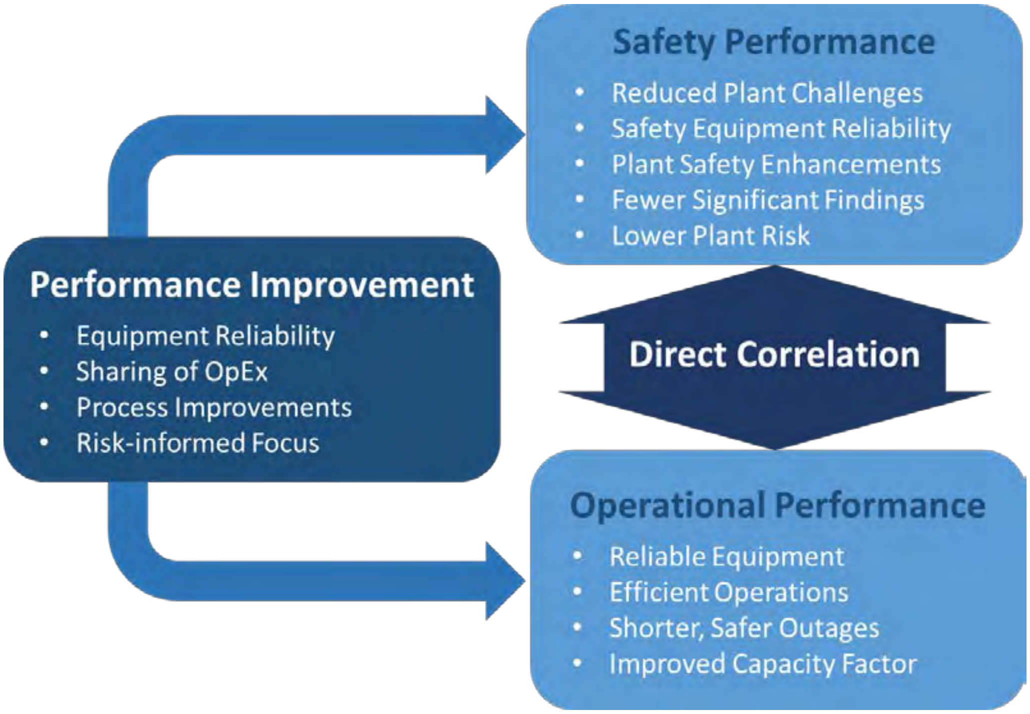



***Figure 9 – Performance-Safety Nexus***

As depicted in Figure 9, a focus on enhancing high equipment reliability translates to fewer equipment failures and higher equipment availability. Both improve operational performance and both result in safer plant operation. A reduction in unplanned reactor trips, reduced in part by high equipment reliability, leads to a higher capacity factor but also reduces the potential for transients that can challenge safe plant operation. The sharing and evaluation of operating experience ensures that challenges are avoided to the benefit of both operational and safety performance. The use of plant PRAs early in the development of process improvements provides assurance that changes provide the desired benefits without compromising plant safety. Maintaining a risk-informed focus in all phases of operation provides a common benefit to both operational and safety performance.

### 3.3 Worker Safety Improvements

An often unstated, but important metric is worker safety. The importance that the nuclear industry places on worker safety is clearly demonstrated by the low incidence of worker injuries as shown in data compiled by the Bureau of Labor Statistics (Figure 10). These statistics show that nuclear workers are a factor of 3 safer than the remainder of electric power generation and an order of magnitude safer than industry as a whole.

The importance of worker safety is also demonstrated through continued attention to reducing and maintaining a low worker radiological exposure. As shown in Figure 11, the average worker exposure in the commercial nuclear power industry has dropped by a factor of eight over the past 40 years.

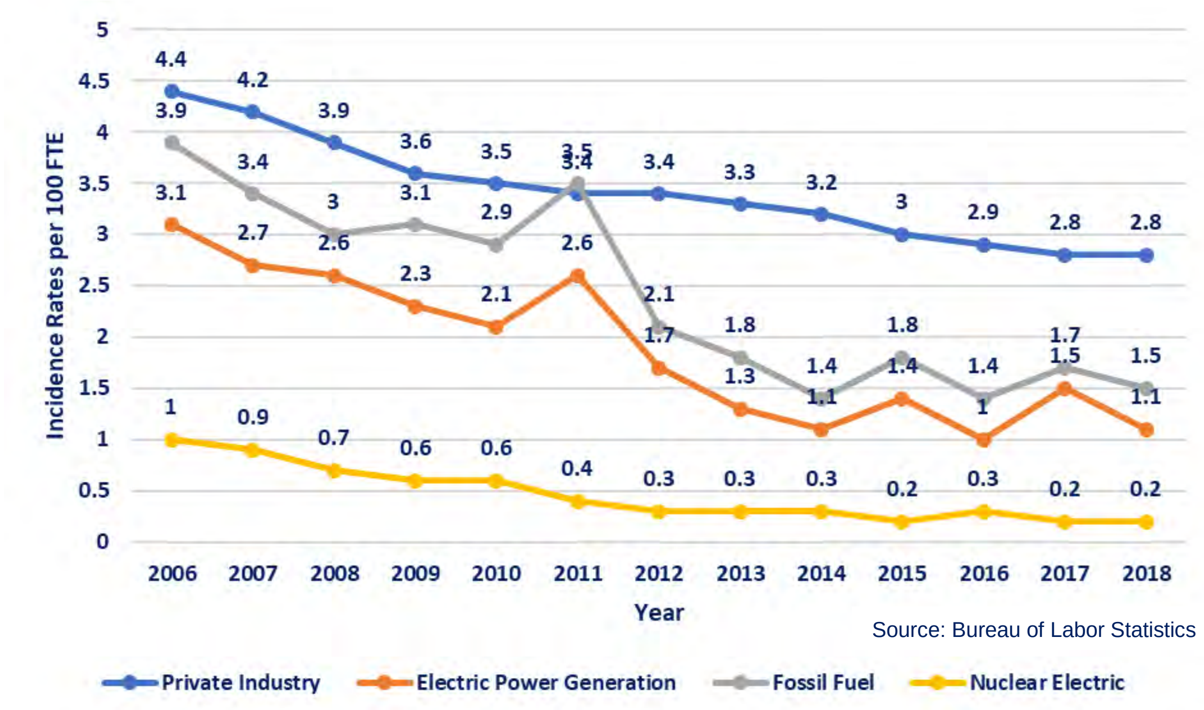



*Figure 10 - Worker Injury Incidence Rate*

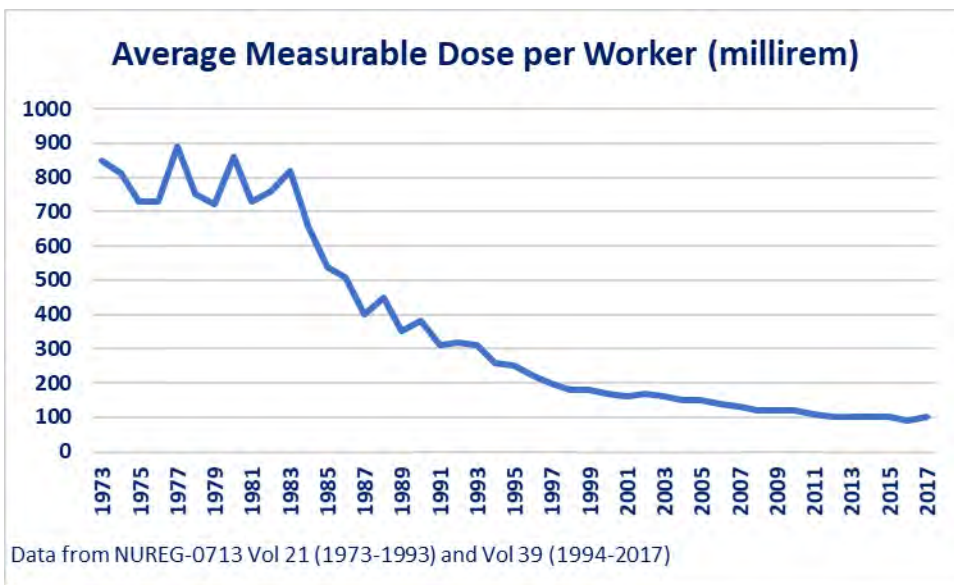



*Figure 11- Average Measurable Dose per Worker (millirem)*

## 3.4 Improved Safety Trend shown through Risk Metrics

The same performance improvements that have improved operational and safety metrics are also reflected in reductions in risk. The primary risk metrics used today are core damage frequency (CDF) and large early release frequency (LERF). These metrics are obtained for each plant from PRA models established for each plant.

It is important to note the connection between the risk metrics generated by PRA models and compliance with the regulations. A PRA model assumes that the plant is in full compliance with the regulations and a plant's licensing basis, so the calculated CDF and LERF values represent the residual plant risk that exists once the regulations are met. The NRC uses risk to determine if additional regulatory requirements are necessary, as discussed in 10 CFR 50.109, "Backfitting," promulgated in 1988. For example, the NRC used risk insights to determine that the residual risk stemming from the failure to insert all control rods upon a shutdown signal warranted additional regulatory attention and promulgated 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transients without Scram (ATWS) Events for Light-water Cooled Nuclear Power Plants," in 1984. In addition, the NRC promulgated 10 CFR 50.63, "Loss of All Alternating Current Power," in 1988 to reduce the residual risk from station blackout events. The NRC and the industry recognize the complementary nature of risk and compliance and use both in ensuring adequate protection of public health and safety. PRA is also used to determine the significance of non-compliance with a regulatory requirement or element of a licensing basis as is done in the Significance Determination Process of the ROP. This result is then used to determine the appropriate regulatory action to address the non-compliance based on the incremental increase in residual risk.

Figure 12 shows the industry average CDF has improved by a factor of 10. This steady reduction in CDF and LERF since the early 1990s has been driven primarily by risk-informed initiatives, continued plant and equipment performance improvements, and plant enhancements. In addition, improvements to PRA models have given a clearer picture of actual risk.

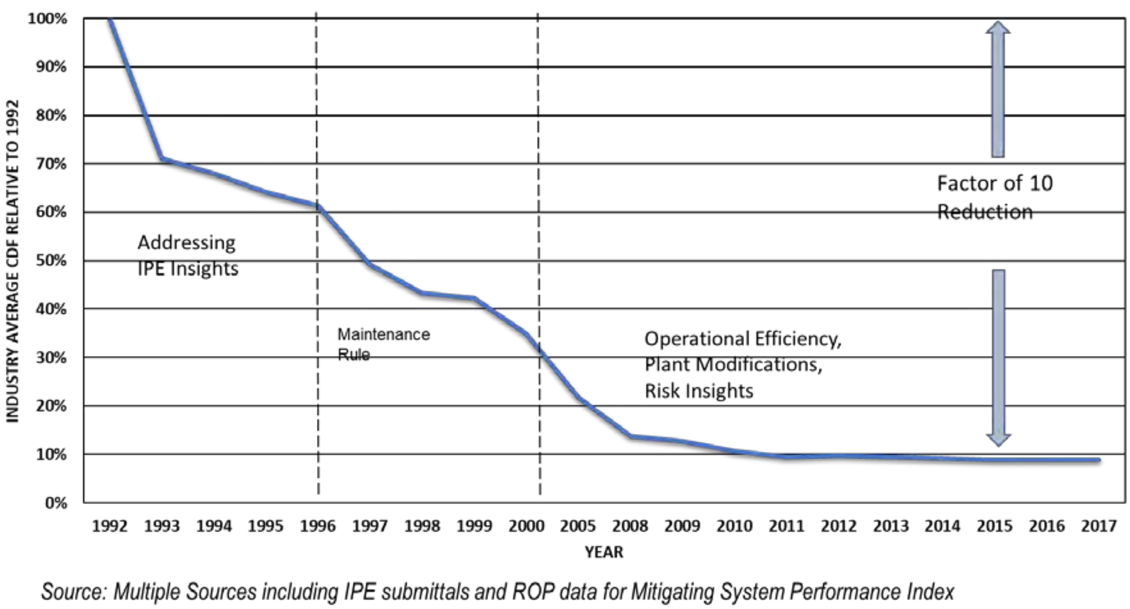



*Figure 12 - Industry Average CDF Trend*

The improvement in safety is further illustrated by results from a sensitivity study (Figure 13) that compared the safety impact of changes in initiating event frequencies and equipment performance since the early 1990s (See Section 4.2). This evaluation eliminates the impact of PRA model changes by relying on NRC Standardized Plant Analysis Risk (SPAR) models and NRC equipment reliability data exclusively. Thus, the NRC's own data and models show that improvements in equipment and operational performance have improved safety by a factor of 3 to 7 for broad range of plant designs.

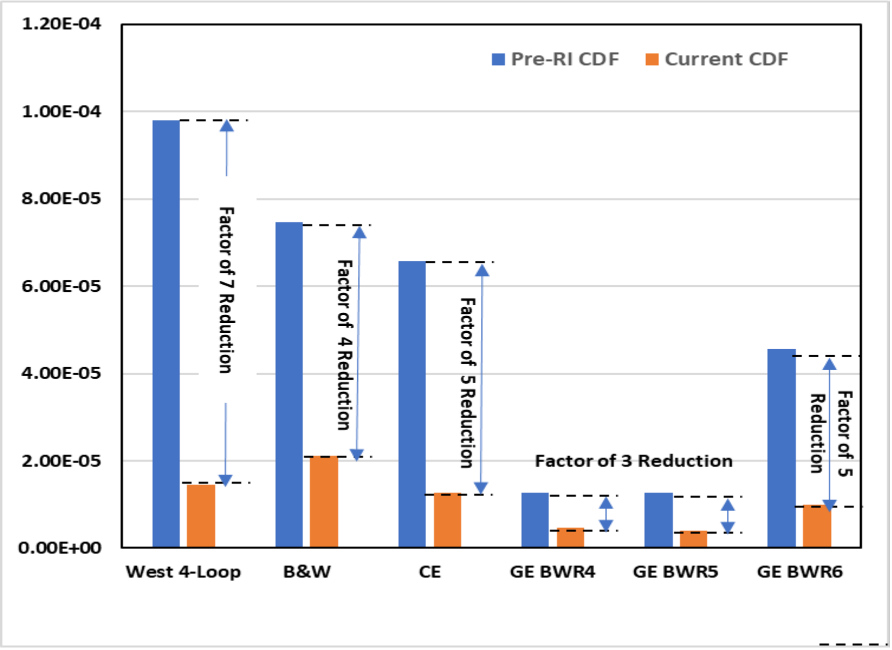



*Figure 13 - Impact on CDF of improved equipment performance and reduced initiating event frequency*

# 4 RISK-INFORMED FOCUS IMPROVES SAFETY PERFORMANCE

The improvement in industry safety performance is easily shown by comparing the industry average CDF as a function of time. As shown in Figure 12, there has been an order of magnitude decrease in the industry average CDF since the early 1990s. While the overall improvement can be attributed to many factors, a key factor to improvements in safety has been a number of risk-informed initiatives that enable plants to identify potential vulnerabilities, outcomes and consequences; and then prioritize actions that have the greatest benefit to plant safety. Since the early 1990s, U.S. nuclear power plants have undertaken several risk-informed activities aimed at improving plant safety performance. These include plant modifications in response to Generic Letter 88-20, “Individual Plant Examination for Severe Accident Vulnerabilities (IPE);” actions taken in accordance with 10 CFR 50.65, “Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” the so-called, “Maintenance Rule;” and plant changes enabled by 10 CFR 50.48(c), “Alternate Fire Protection Rule,” and NFPA-805, “Performance-Based Standard for Fire Protection.” These activities have increased the availability and reliability of systems and components and have reduced the likelihood of initiating events.

The benefits of risk-informed initiatives include both safety and operational benefits. Risk-informed initiatives allow both industry and NRC to focus on issues that are most important to safety, yielding safety benefits and reducing risk. Operational performance benefits arise from increased flexibility, higher quality maintenance, greatly reduced focus on non-safety-significant systems and reduced outages.

## 4.1 Value of Risk-Informed Focus

Each of the risk-informed activities implemented since the 1990s brings its own unique blend of operational and safety benefits but they all share a common value: an improved focus on issues that are important to safety.

<u>Maintenance Rule</u>

The Maintenance Rule (10 CFR 50.65) involves the identification and monitoring of risk-significant structures, systems and components (SSCs). Operationally, the focus on safety-significant SSCs has led to a decreased focus on unimportant SSCs, which has improved operational efficiency and effectiveness. Additionally, the rule supported conduct of online maintenance, allowing licensees to conduct more routine maintenance between refueling outages. On-line maintenance reduces availability while the maintenance is performed but increases equipment reliability. The net outcome has been an overall improvement in the total availability of key equipment. The result has been a net risk reduction across the industry.

<u>Reactor Oversight Process</u>

As previously described, the ROP adopted a risk-informed approach to oversight and assessment of licensee performance. The ROP’s performance indicators incentivize improvements in the reliability of risk-significant SSCs and the effectiveness of key processes that have, in turn, resulted in a net risk reduction and increased focus on safety-significant


***Figure 14 - ROP Significance Determination***

activities at operating plants. Improvements in industry performance is readily seen in the performance indicator trends provided in Appendix B.

The inspection program uses a risk-informed approach to select areas to inspect based on their importance to potential risk, past operational experience, and regulatory requirements. A risk-informed significance determination process (SDP) is used to determine the risk significance of inspection findings, assigning a color to each finding based on its safety or security significance (Figure 14). Industry improvement in this area is readily seen in the January 2020 summary of inspection results for 2019 (Figure 15). This summary shows either no findings (gray) or green findings such that there were no inspection findings in 2019 with a safety/security significance greater than green.

2019 Inspection Finding Performance Summary

| Plants | IE | MS | BI | EP | ORS | PR | Sec |
|---|---|---|---|---|---|---|---|
| Arkansas Nuclear 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Arkansas Nuclear 2 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Beaver Valley 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | Green |
| Beaver Valley 2 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | Green |
| Braidwood 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Braidwood 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Browns Ferry 1 | No Findings | Green | No Findings | No Findings | Green | No Findings | No Findings |
| Browns Ferry 2 | No Findings | Green | No Findings | No Findings | Green | No Findings | No Findings |
| Browns Ferry 3 | Green | Green | No Findings | No Findings | Green | No Findings | No Findings |
| Brunswick 1 | No Findings | Green | Green | Green | Green | No Findings | No Findings |
| Brunswick 2 | Green | Green | Green | Green | Green | No Findings | No Findings |
| Byron 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Byron 2 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Callaway | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Calvert Cliffs 1 | No Findings | No Findings | Green | No Findings | No Findings | No Findings | No Findings |
| Calvert Cliffs 2 | No Findings | No Findings | Green | No Findings | No Findings | No Findings | No Findings |
| Catawba 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Catawba 2 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | Green |
| Clinton | Green | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Columbia Generati | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Comanche Peak 1 | No Findings | Green | Green | Green | No Findings | No Findings | No Findings |
| Comanche Peak 2 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Cooper | Green | Green | Green | No Findings | No Findings | No Findings | Green |
| D.C. Cook 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| D.C. Cook 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Davis-Besse | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Diablo Canyon 1 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Diablo Canyon 2 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Dresden 2 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Dresden 3 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Duane Arnold | Green | No Findings | No Findings | No Findings | Green | No Findings | No Findings |
| Farley 1 | No Findings | Green | No Findings | No Findings | Green | No Findings | Green |
| Farley 2 | No Findings | No Findings | Green | No Findings | Green | No Findings | Green |
| Fermi 2 | No Findings | Green | Green | No Findings | No Findings | No Findings | Green |

| Plants | IE | MS | BI | EP | ORS | PR | Sec |
|---|---|---|---|---|---|---|---|
| FitzPatrick | No Findings | No Findings | Green | No Findings | Green | No Findings | No Findings |
| Ginna | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Grand Gulf 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Harris 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Hatch 1 | No Findings | No Findings | No Findings | No Findings | Green | No Findings | Green |
| Hatch 2 | No Findings | Green | No Findings | No Findings | Green | No Findings | Green |
| Hope Creek 1 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Indian Point 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Indian Point 3 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| LaSalle 1 | No Findings | Green | No Findings | No Findings | Green | No Findings | No Findings |
| LaSalle 2 | Green | Green | Green | No Findings | Green | No Findings | No Findings |
| Limerick 1 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Limerick 2 | Green | Green | Green | No Findings | No Findings | No Findings | No Findings |
| McGuire 1 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| McGuire 2 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Millstone 2 | No Findings | Green | Green | No Findings | No Findings | No Findings | Green |
| Millstone 3 | Green | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Monticello | No Findings | No Findings | Green | No Findings | No Findings | No Findings | Green |
| Nine Mile Point 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Nine Mile Point 2 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| North Anna 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| North Anna 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Oconee 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Oconee 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Oconee 3 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Palisades | Green | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Palo Verde 1 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Palo Verde 2 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Palo Verde 3 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Peach Bottom 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Peach Bottom 3 | Green | Green | Green | No Findings | No Findings | No Findings | Green |
| Perry 1 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Point Beach 1 | Green | No Findings | No Findings | No Findings | Green | No Findings | Green |
| Point Beach 2 | No Findings | No Findings | No Findings | No Findings | Green | No Findings | Green |

| Plants | IE | MS | BI | EP | ORS | PR | Sec |
|---|---|---|---|---|---|---|---|
| Prairie Island 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Prairie Island 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | Green |
| Quad Cities 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | Green |
| Quad Cities 2 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| River Bend 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Robinson 2 | No Findings | No Findings | Green | No Findings | No Findings | No Findings | No Findings |
| Saint Lucie 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Saint Lucie 2 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Salem 1 | No Findings | Green | Green | No Findings | Green | No Findings | No Findings |
| Salem 2 | Green | Green | Green | No Findings | Green | No Findings | No Findings |
| Seabrook 1 | No Findings | No Findings | No Findings | Green | No Findings | No Findings | Green |
| Sequoyah 1 | No Findings | Green | No Findings | No Findings | No Findings | Green | No Findings |
| Sequoyah 2 | No Findings | Green | No Findings | No Findings | No Findings | Green | No Findings |
| South Texas 1 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| South Texas 2 | Green | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Summer | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Surry 1 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Surry 2 | Green | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Susquehanna 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Susquehanna 2 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Three Mile Island 1 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Turkey Point 3 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Turkey Point 4 | No Findings | Green | No Findings | No Findings | No Findings | No Findings | No Findings |
| Vogtle 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings |
| Vogtle 2 | No Findings | No Findings | Green | No Findings | No Findings | No Findings | No Findings |
| Waterford 3 | Green | Green | Green | No Findings | Green | No Findings | Green |
| Watts Bar 1 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Watts Bar 2 | No Findings | Green | Green | No Findings | No Findings | No Findings | No Findings |
| Wolf Creek 1 | No Findings | No Findings | No Findings | No Findings | No Findings | No Findings | Green |

This summary provides the color designation of the most significant inspection findings over the previous 4 quarters. (Current data as of 1/17/2020)

***Figure 15 - ROP Inspection Finding Performance Summary for 2019***

Technical Specification Enhancements

A number of risk-informed technical specification changes have been developed through industry initiatives and through plant-specific action. Many of the changes have improved maintenance management on key equipment and risk-significant SSCs. Through the use of a configuration risk management process, proper control on plant configuration during key maintenance activities is maintained to minimize the impact of out-of-service equipment and testing. These controls do not exist in traditional deterministic technical specifications. Operationally, risk-informed technical specifications provide greater flexibility in maintenance scheduling, ensure higher quality maintenance is performed and enable shorter, less complex outages.

Risk-Informed In-Service Inspections

Traditional in-service inspection (ISI) programs identify the required inspections based on deterministic criteria and/or a random selection process. Risk-informed ISI uses operating experience and risk insights to target pipe segments and components that present the greatest risk, which considers both the likelihood and consequences of failure, so that most time and attention are focused on the most risk-significant welds. The result is improved safety and also fewer inspections performed during outages that are not safety significant, lowering personnel exposures.

Special Treatment Requirements (10 CFR 50.69)

Under the rule codified in 2004, licensees are able to categorize and modify treatment of SSCs based on their safety significance. Under this regulation, the special treatment requirements can be reduced for safety related SSCs that are determined to be of low safety significance but increases the requirements for non-safety related components that are safety significant. This improves safety by focusing time and attention on the most safety significant SSCs and overall enables reductions and associated savings in in-service testing, local leak-rate testing, Maintenance Rule scope, parts procurement, work control, and preventive maintenance tasks.

Fire Protection (50.48(c)/NFPA-805)

The NRC promulgated a fire protection rule change that provided an optional (voluntary) approach to demonstrating post fire safe shutdown capability that involved a risk-informed, performance-based process. This risk-informed, performance-based option allowed licensees to commit to the provisions of 10 CFR 50.48(c) instead of the deterministic provisions associated with 10 CFR 50.48(b). Approximately half of the U.S. fleet took advantage of this option and submitted License Amendment Requests to change to this optional approach. As part of this license change process most licensees did not rely on previously granted exemptions from the fire protection regulation. Instead, the licensees performed a comprehensive risk-informed, performance-based examination of the in-situ plant configuration. Almost all plants that transitioned to 10 CFR 50.48(c) performed plant modifications that resulted in a decrease in the plant core damage frequency.

Plants that transitioned to 10 CFR 50.48(c) were also required to report the post transition plant risk metrics and the net change in risk as compared to a hypothetical plant configuration that complies with 10 CFR 50.48(b). As noted in NRC Regulatory Guide 1.205, any risk increase is required to be consistent with the provisions of NRC Regulatory Guide 1.174. While some plants reported risk increases that were within the allowable limits provided in Regulatory Guide 1.174, about half of the transitioning plants report a net reduction in overall plant risk. When the entire population of transitioning plants is evaluated on a collective basis, the aggregate risk was reduced roughly by 50 percent.

## 4.2 Risk-Informed Performance Sensitivity Study

To demonstrate the impact of risk-informed initiatives on plant performance and safety over the past two decades, a sensitivity study was performed to assess the change in CDF over the period from early 1990s to present day. To conduct the study NRC SPAR models were used for six common plant types:

- Westinghouse 4-loop
- B&W
- Combustion Engineering
- GE BWR 4
- GE BWR 5
- GE BWR 6

Two sets of cases were performed. The first set, referred to as the “Current CDF” used SPAR models containing data that reflects the current performance at the six plants. For the second set, referred to as the “Pre-RI CDF,” the initiating event frequencies and component data were replaced with NRC published data that preceded the implementation of risk-informed initiatives. The sensitivity study only addressed changes in the data and took no credit for other safety enhancements implemented over the past 30 years, such as hardware and procedure changes. These changes would further increase the CDF improvement factor shown by the study.

Table 1 and Figure 16 present a summary of CDF results for each plant. On average, CDF was shown to have improved by a factor of 4.3. This improvement reflects the reduction in initiating event frequencies (improvement factor of 3.0 with a range of 1.8 to 4.9) and component reliability (improvement factor is 2.1 with a range of 1.3 to 3.4). Test and maintenance unavailability increased slightly due primarily to risk-informed initiatives that extend allowed outage times and permit more online maintenance. The composite values are shown in Figure 17.

The impact of a small increase in planned unavailability is minimized by the more pronounced reduction in failure rates. This leads to an overall positive improvement factor for component-based data. The combined component-based improvement factor is 1.9 with a range of 1.3 to 2.6.

**Table 1 - Impact of Risk-Informed Initiatives on CDF**

| Plant Type | Pre RI CDF | Current CDF | Improvement Factor |
|---|---|---|---|
| Westinghouse 4-Loop | $9.80 \times 10^{-5}$ | $1.45 \times 10^{-5}$ | 6.8 |
| B&W | $7.46 \times 10^{-5}$ | $2.12 \times 10^{-5}$ | 3.5 |
| Combustion Engineering | $6.58 \times 10^{-5}$ | $1.28 \times 10^{-5}$ | 5.1 |
| GE BWR4 | $1.27 \times 10^{-5}$ | $4.72 \times 10^{-6}$ | 2.7 |
| GE BWR5 | $1.26 \times 10^{-5}$ | $4.01 \times 10^{-6}$ | 3.1 |
| GE BWR6 | $4.55 \times 10^{-5}$ | $1.00 \times 10^{-5}$ | 4.6 |

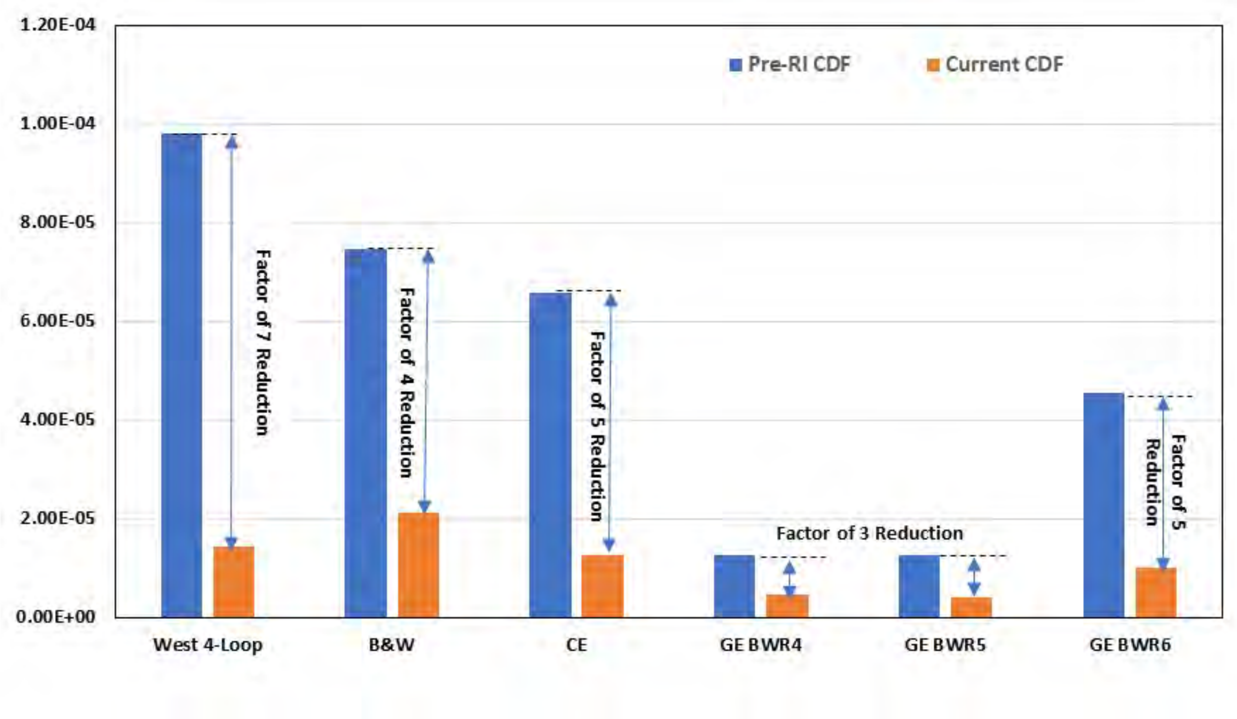



*Figure 16 - Impact on CDF (CDF Improvement)*

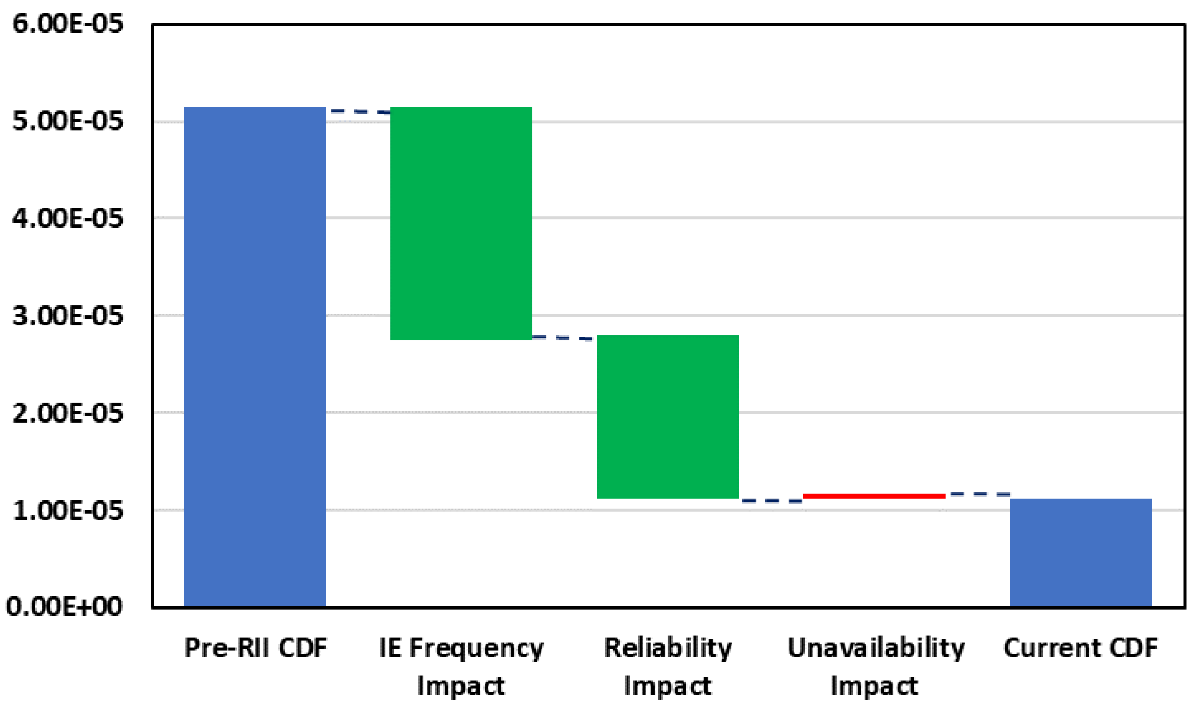



*Figure 17 - Impact on CDF (Contribution to Improvement by Data Type)*

## 5 CONCLUSIONS

U.S. nuclear industry performance is at the highest levels ever. The focus on performance has led to improvements in both safety and operational performance.

There are many factors influencing this improvement including the cultivation of a strong safety and reliability culture by utilities, a strong independent nuclear regulator in the NRC, an independent industry excellence organization (INPO), and the NRC's adoption of a risk-informed safety focus. Over the past 20 years, improving plant performance has been coupled with the enhanced safety focus provided by a risk-informed approach that focuses resources on the most safety significant issues. Today, the U.S. nuclear industry is performing the highest levels of safety and reliability in the world.

The unequivocal picture provided by these performance indicators supports the following:

- **U.S. Industry Performance at All Time Highs**
- **Industry Performance Levels Improve Safety**
- **Risk-informed Focus Improves Safety**

# APPENDIX A: INPO PERFORMANCE INDICATORS

| Figure | Title |
|---|---|
| A1 | Unit Capability Factor |
| A2 | Industry Scram Trend |
| A3 | Online Reliability Loss Factor |
| A4 | Fuel Performance |
| A5 | Safety System Performance |
| A6 | Total Industrial Accident Rate |
| A7 | Chemistry Effectiveness Indicator – PWR |
| A8 | Chemistry Effectiveness Indicator - BWR |
| A9 | Collective Radiation Exposure – PWR |
| A10 | Collective Radiation Exposure - BWR |

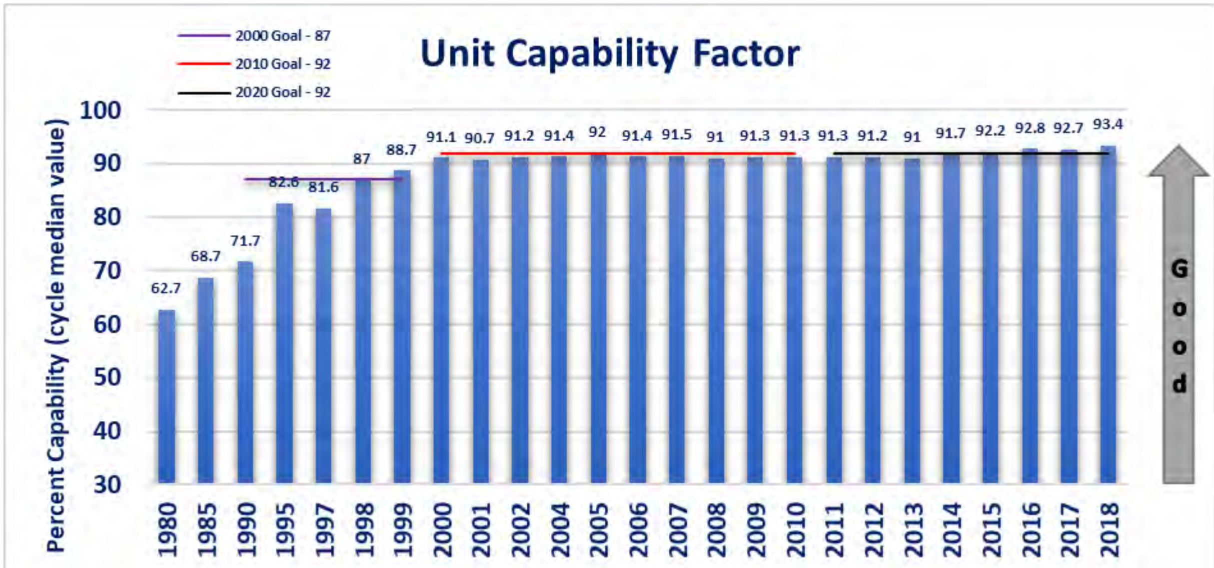



**Figure A1 – Unit Capability Factor**

<u>Unit Capability Factor</u>
This indicator measures the amount of time the plant is online and producing electricity. Plants with a high unit capability are successful in reducing unplanned outages and completing scheduled work effectively during planned outages. As seen in Figure A1, this indicator has improved from 62.7% in 1980 to 93.4% in 2018, exceeding the 2020 goal of 92%.

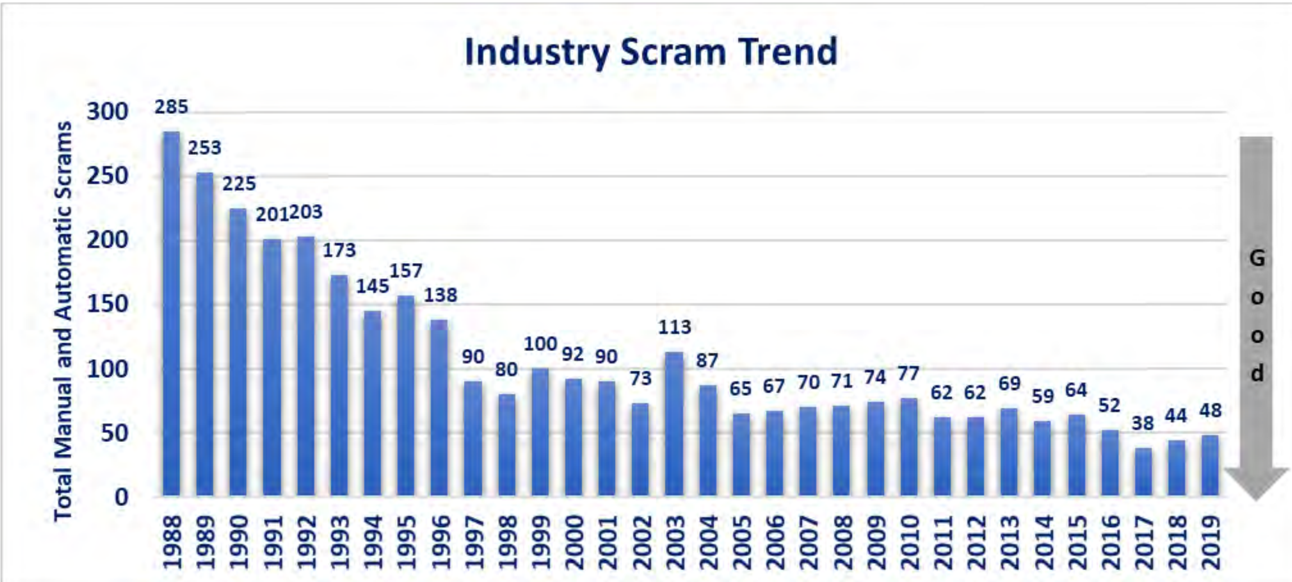



**Figure A2 – Industry Scram Trend**

<u>Industry Scram Trend</u>

This indicator shows the total number of manual and automatic reactor scrams that occurred per year. As seen in Figure A2, this indicator has seen significant improvement since the 1980s, with the number of reactor trips decreasing from greater than 250 per year to less than 50.

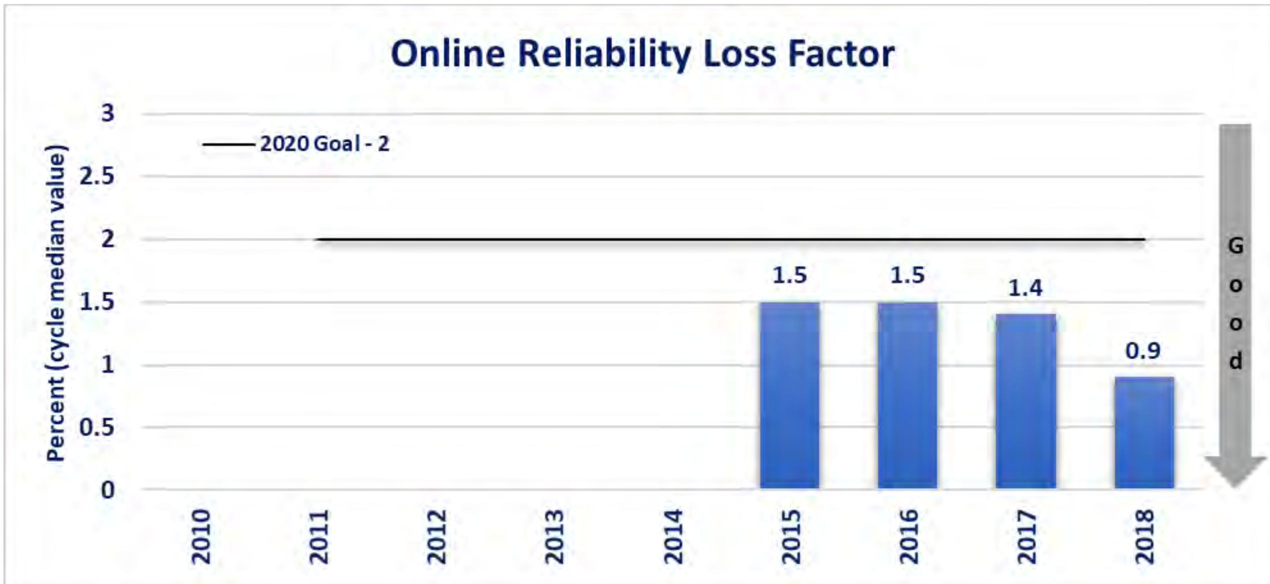



**Figure A3 – Online Reliability Loss Factor**

<u>Online Reliability Loss Factor</u>
This new industry performance indicator measures the ratio of all energy generation losses, adjusted for refueling and exempt activity losses. This indicator, while new, has already shown a 40% improvement.

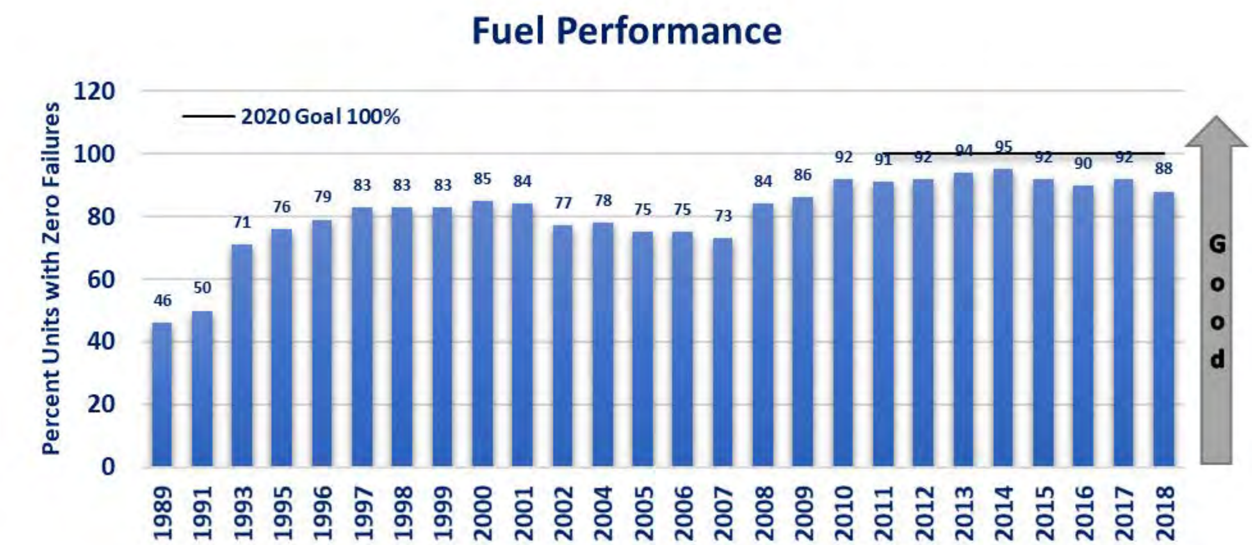



**Figure A4 – Fuel Performance**

<u>Fuel Performance</u>
This indicator shows the percentage of units with no failures in the metal barrier surrounding fuel and has shown steady improvement. The industry's long-term goal is that units operate with zero fuel failures.

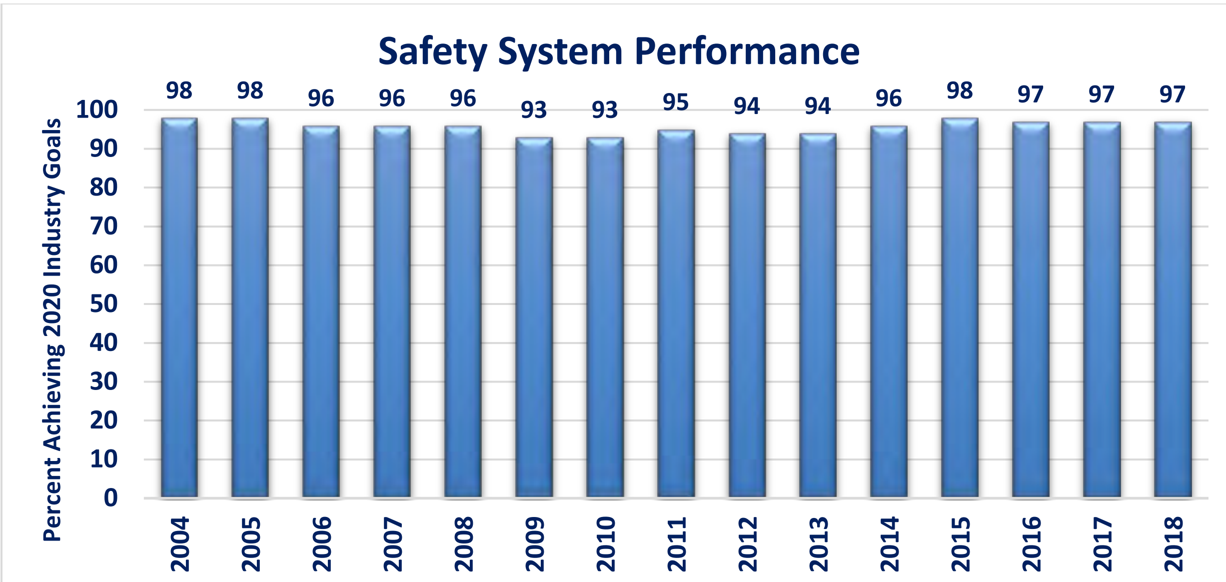



**Figure A5 – Safety System Performance**

<u>Safety System Performance</u>
This indicator monitors the availability of three standby safety systems used to respond to unusual situations. The graph shows the percentage of units achieving availability goals.

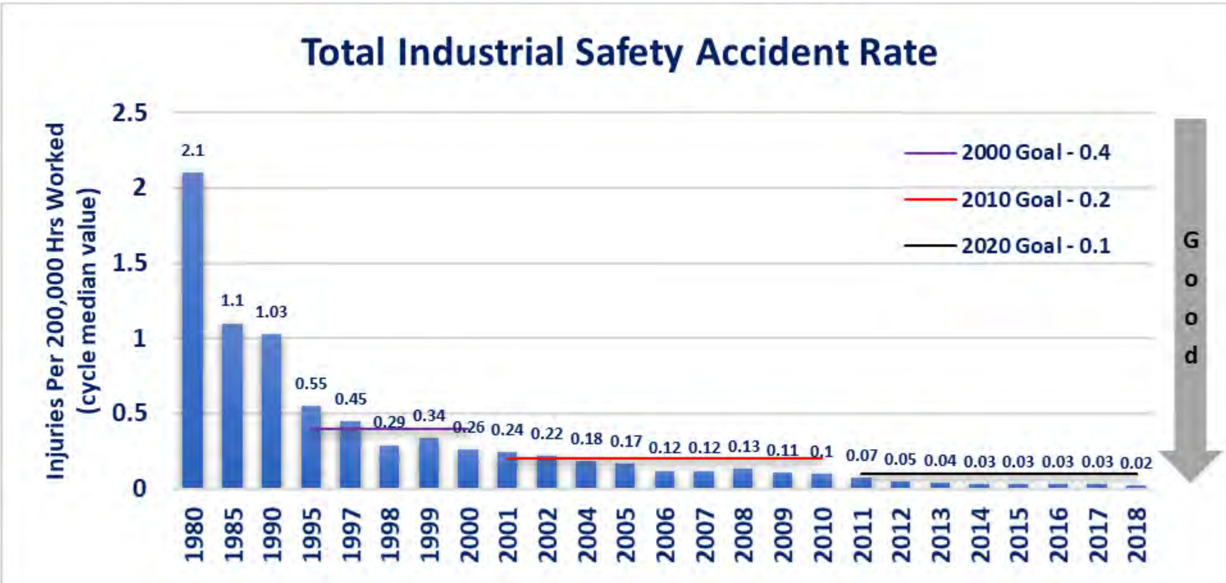



**Figure A6 – Total Industrial Safety Accident Rate**

<u>Total Industrial Safety Accident Rate</u>
This indicator tracks how many industrial accidents per 200,000 worker hours result in lost work time, restricted work or fatalities and demonstrates the importance placed on worker safety.

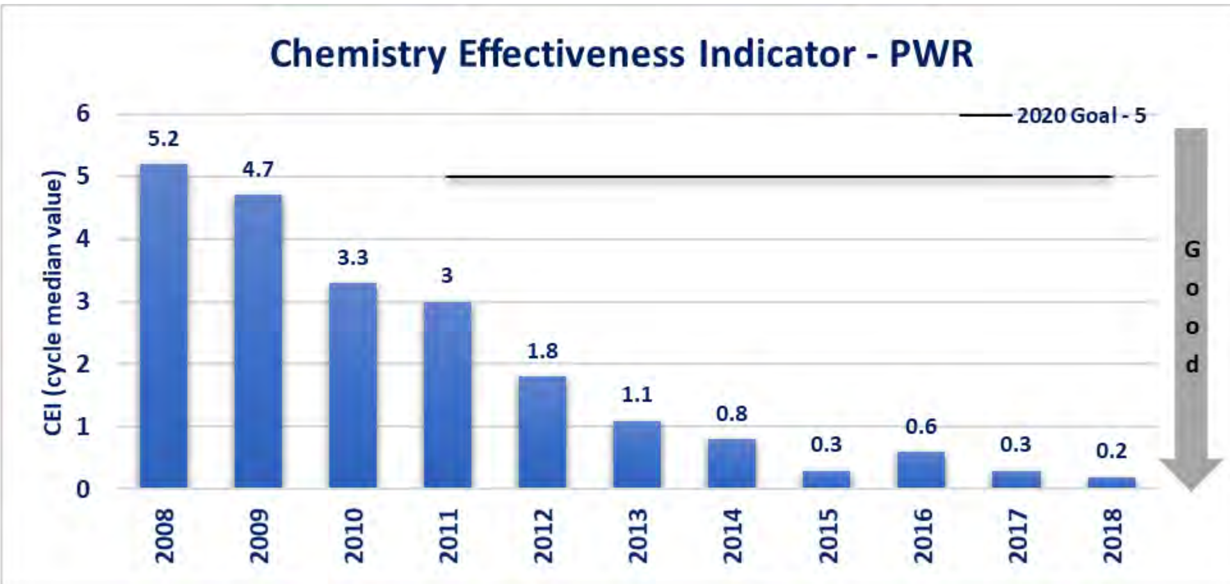



**Figure A7 – Chemistry Effectiveness Indicator – PWR**

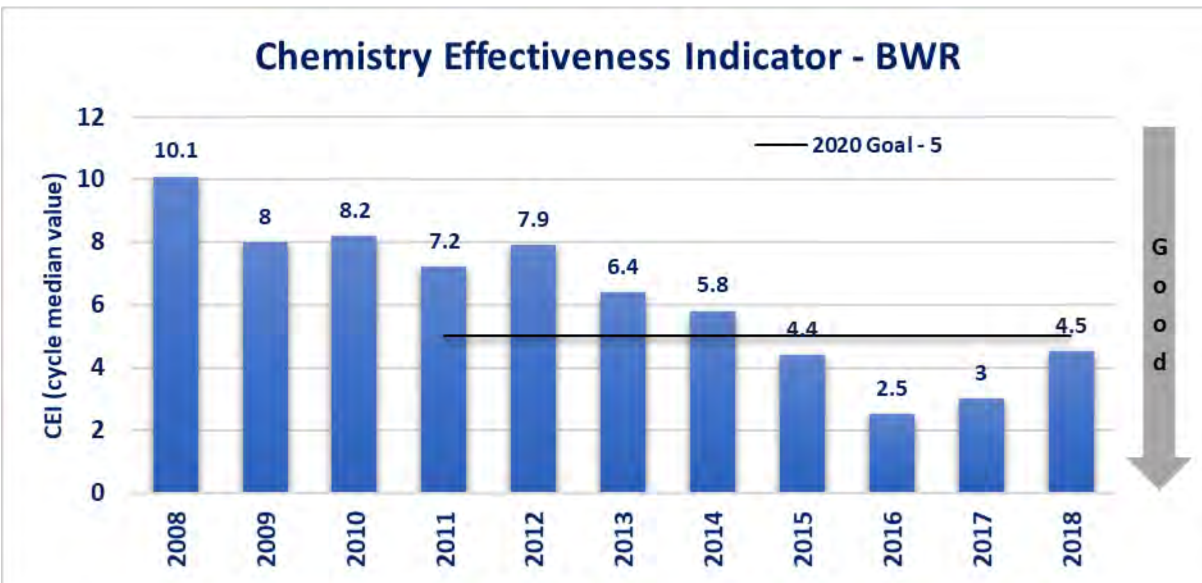



**Figure A8 – Chemistry Effectiveness Indicator – BWR**

<u>Chemistry Effectiveness Indicator</u>

This indicator is a comprehensive measure of overall chemistry performance as related to long-term material degradation. It is based on industry guidelines for water chemistry control and uses a set of five conditions. Lower numbers represent better chemistry control.

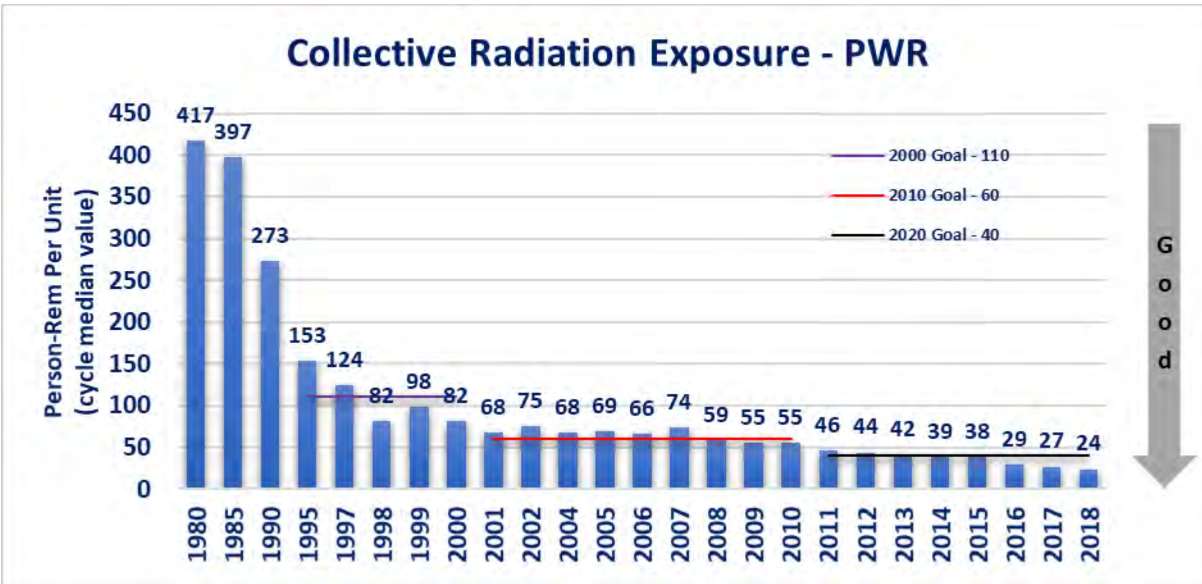



**Figure A9 – Collective Radiation Exposure – PWR**

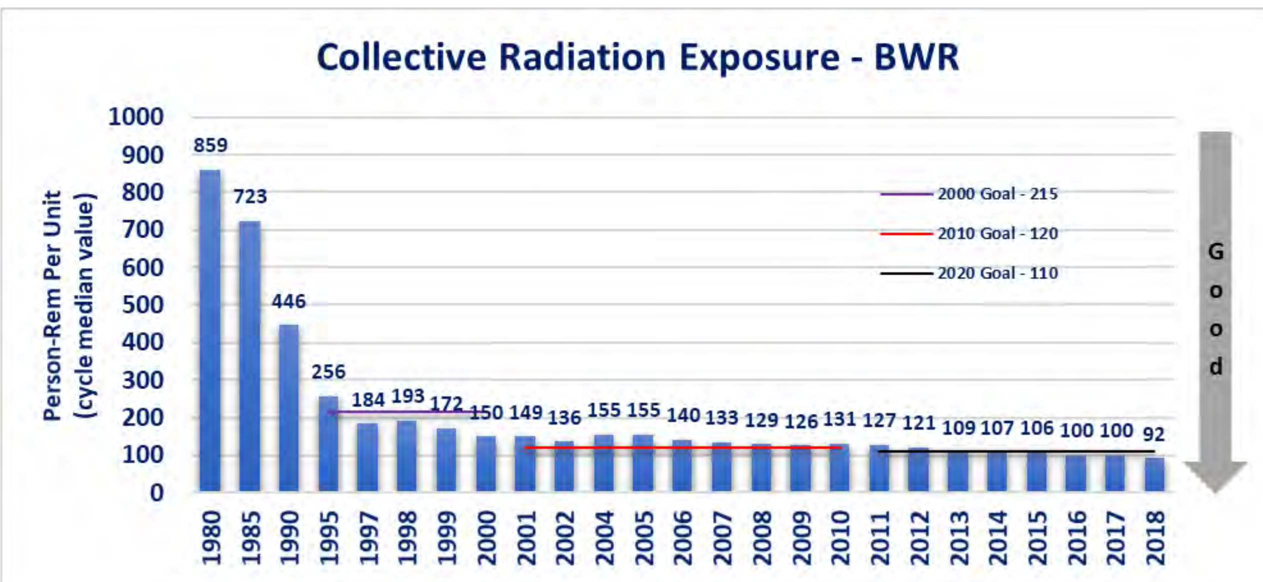



**Figure A10 – Collective Radiation Exposure – BWR**

Collective Radiation Exposure

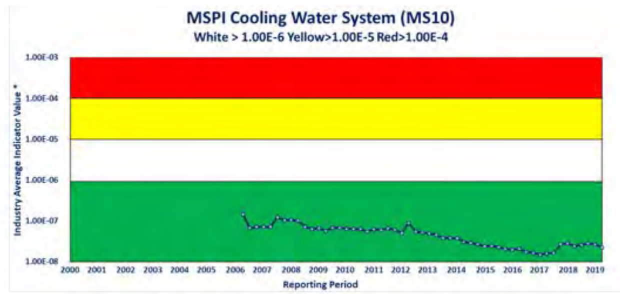
This indicator measures the effectiveness of practices that reduce radiation exposure at plants. Low exposure indicates strong management attention to radiation protection.

# APPENDIX B: NRC REACTOR OVERSIGHT PROCESS INDICATORS

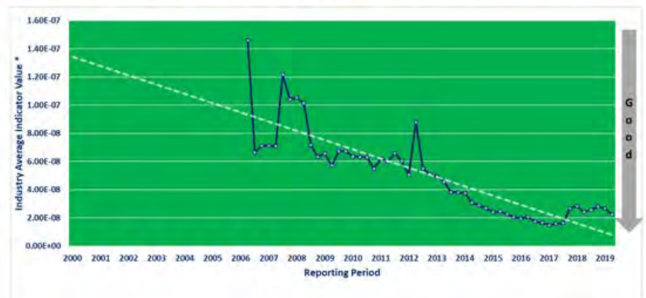
| Figure | Title |
|---|---|
| B1 | Unplanned Scrams (IE01) |
| B2 | Scrams w/ Loss of Normal Heat Removal (IE02) |
| B3 | Unplanned Power Changes (IE03) |
| B4 | Unplanned Scrams w/ Complications (IE04) |
| B5 | Safety System Functional Failures (MS05) |
| B6 | MSPI Emergency AC Power Systems (MS06) |
| B7 | MSPI High Pressure Injection System (MS07) |
| B8 | MSPI Heat Removal System (MS08) |
| B9 | MSPI Residual Head Removal System (MS09) |
| B10 | MSPI Cooling Water System (MS10) |
| B11 | RCS Activity (BI01) |
| B12 | RCS Leakage (BI02) |
| B13 | Drill/Exercise Performance (EP01) |
| B14 | ERO Drill Participation (EP02) |
| B15 | Alert & Notification System (EP03) |
| B16 | Occupational Exposure Control Effectiveness (OR01) |
| B17 | Radiological Effluent Technical Specifications/Offsite Dose Calculation Manual (PR01) |

## Overview of Appendix B Data Presentation

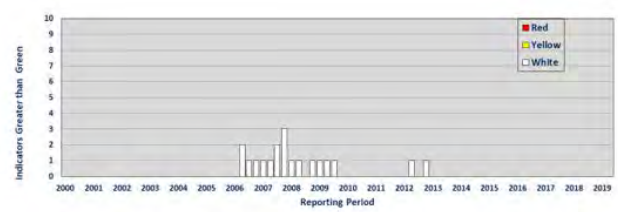
The ROP Performance Indicator data presented in this Appendix includes all current indicators except for the Security Performance Indicator (PP01). PP01 data is not publicly available. Data is also provided for a performance indicator that has since been discontinued (IE02)



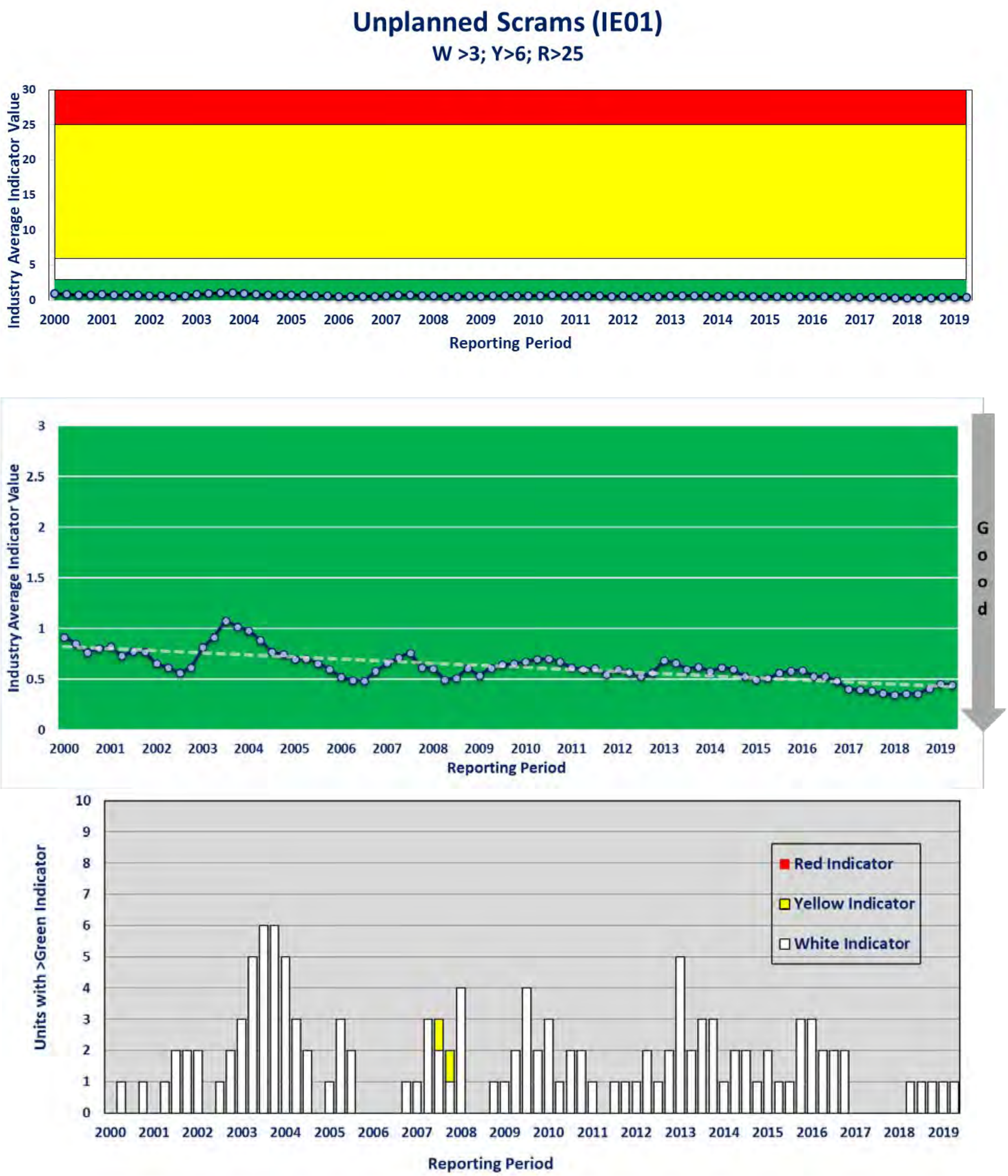

Each Figure presents three charts. The top chart provides the industry-wide unit average for the performance indicator presented on a scale that displays all possible performance thresholds (i.e., Green, White, Yellow, Red). This provides a perspective of how far the average performance indicator results are from safety significance.




The second chart expands the Y-axis scale to more clearly show the trend in industry-wide unit averages.



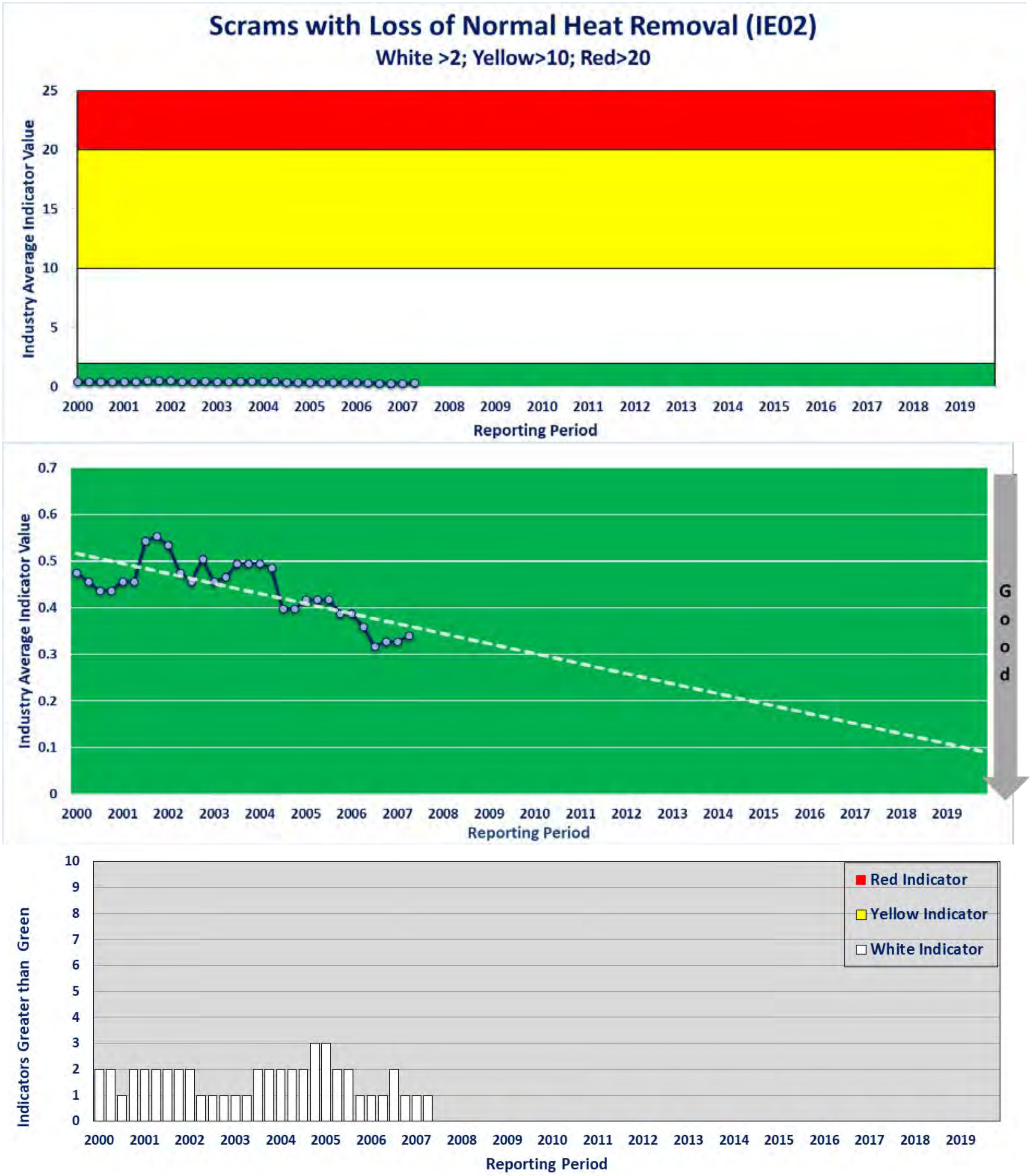

The third chart shows the number (and color) of “greater than green” performance indications for each reporting period. This provides a perspective on the presence of data outliers, which is not provided by the average results presented in the other figures.




**Unplanned Scrams (IE01)** – The number of unplanned scrams during the previous four quarters, both manual and automatic, while critical per 7,000 hours. The scram rate is calculated per 7,000 critical hours because that value is representative of the critical hours of operation in a year for a typical plant.

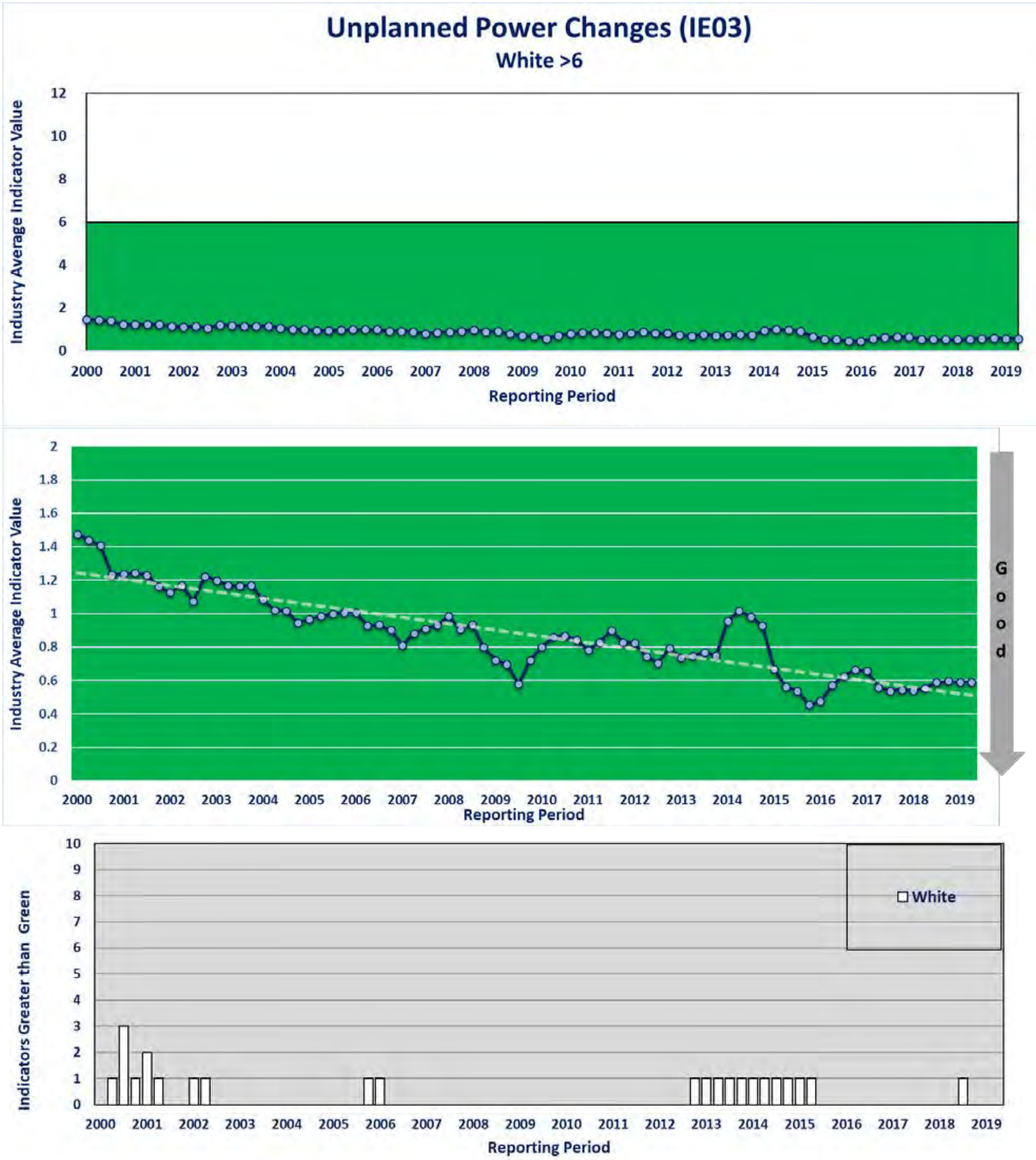
**Figure B1 – Unplanned Scrams (IE01)**



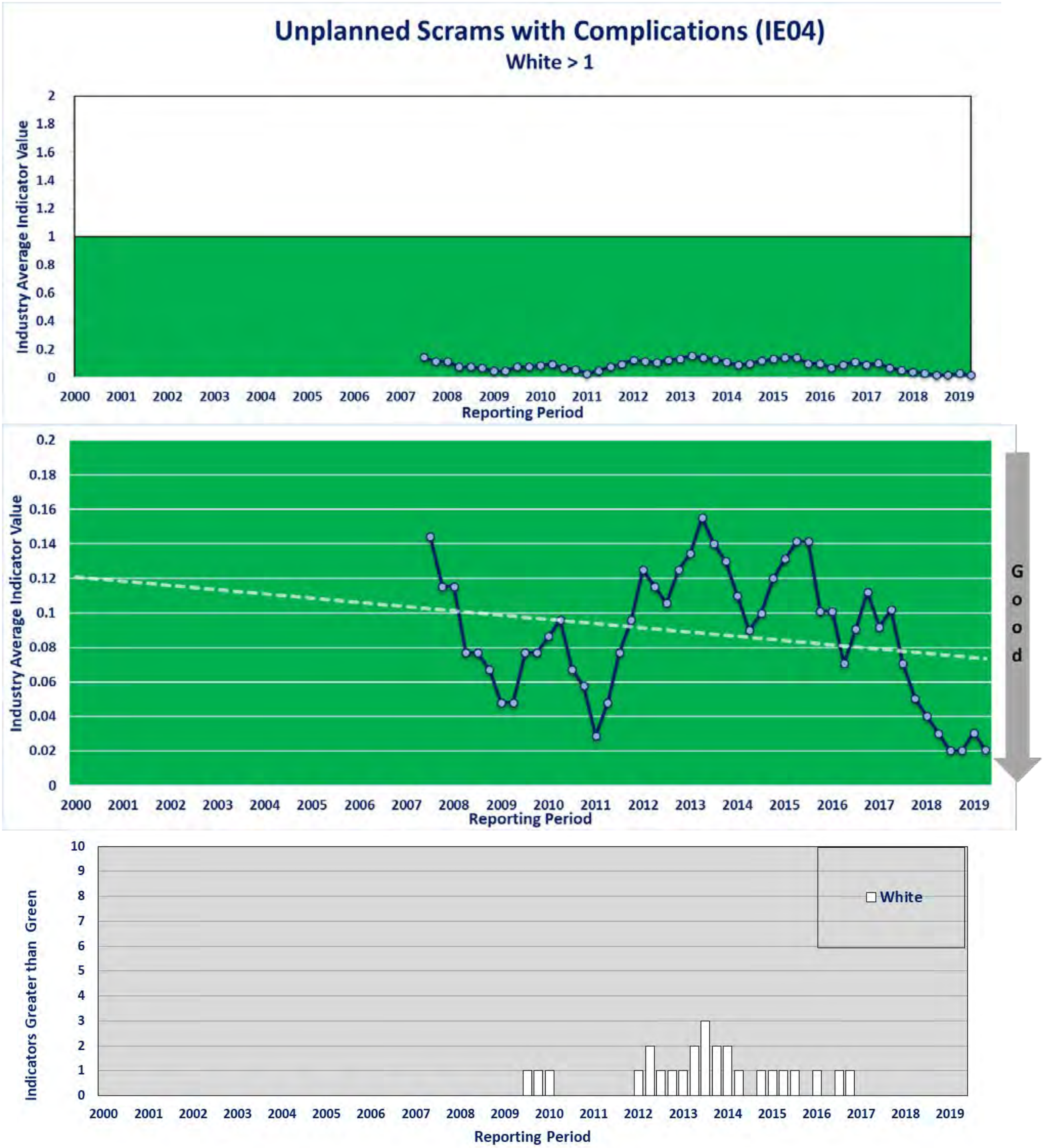

**Scrams with Loss of Normal Heat Removal (IE02)** – The number of unplanned and planned scrams while critical, both manual and automatic, during the previous 12 quarters that also involved a loss of the normal heat removal path through the main condenser prior to establishing reactor conditions that allow use of the plant's normal long term heat removal systems. This indicator was replaced by Unplanned Scrams with Complications (IE04) in 2007.

**Figure B2 – Scrams w/ Loss of Normal Heat Removal (IE02)**



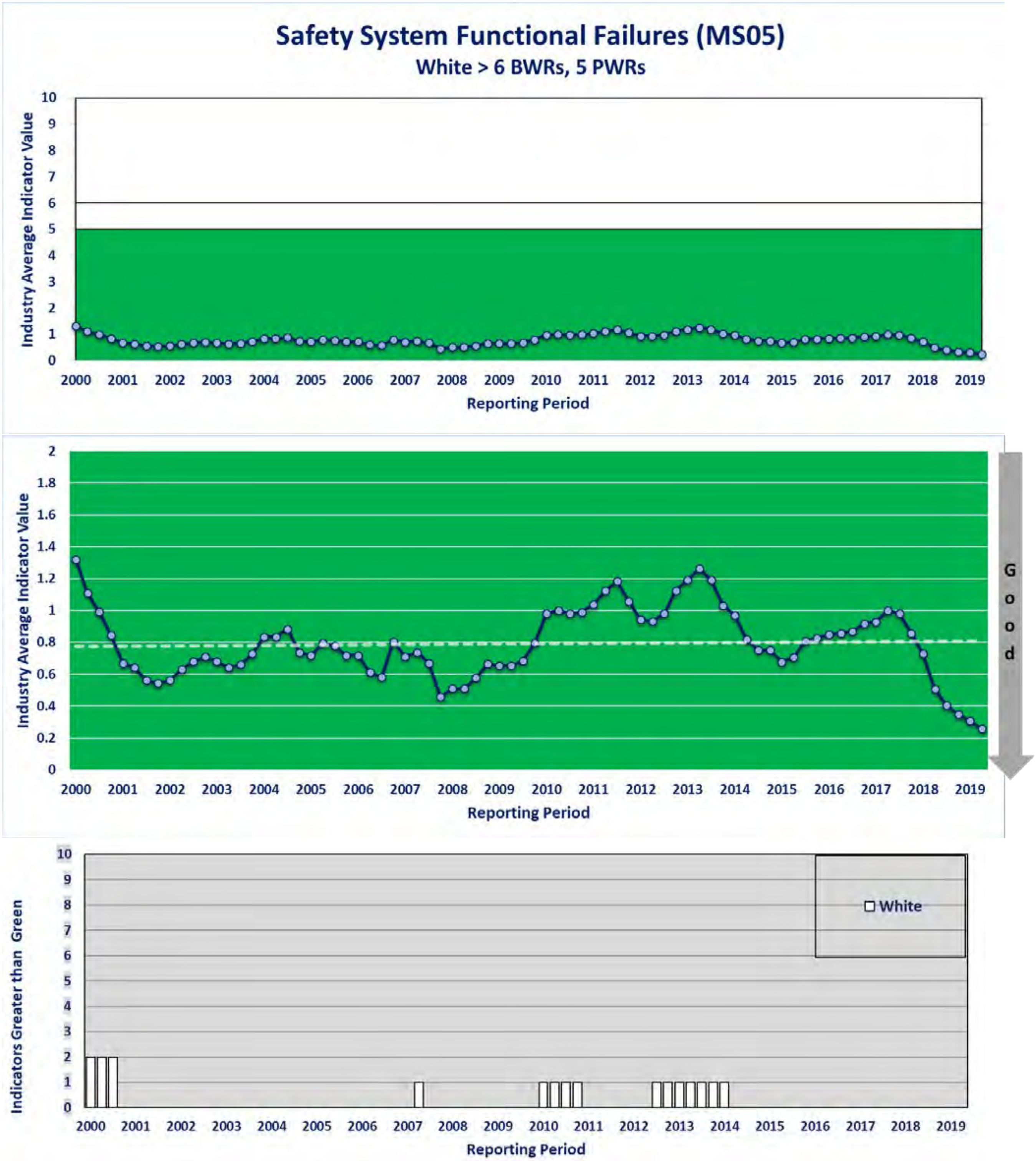

**Unplanned Power Changes (IE03)** – The number of unplanned changes in reactor power of greater than 20-percent full-power, per 7,000 hours of critical operation, excluding manual and automatic scrams.

**Figure B3 – Unplanned Power Changes (IE03)**




**Unplanned Scrams with Complications (IE04)** – The number of unplanned scrams while critical, both manual and automatic, during the previous four quarters require additional operator actions as defined by the flowchart in NEI 99-02 Rev 7, "Regulatory Assessment Performance Indicator Guideline." This indicator replaced Scrams with Loss of Normal Heat Removal (IE02) in 2007.

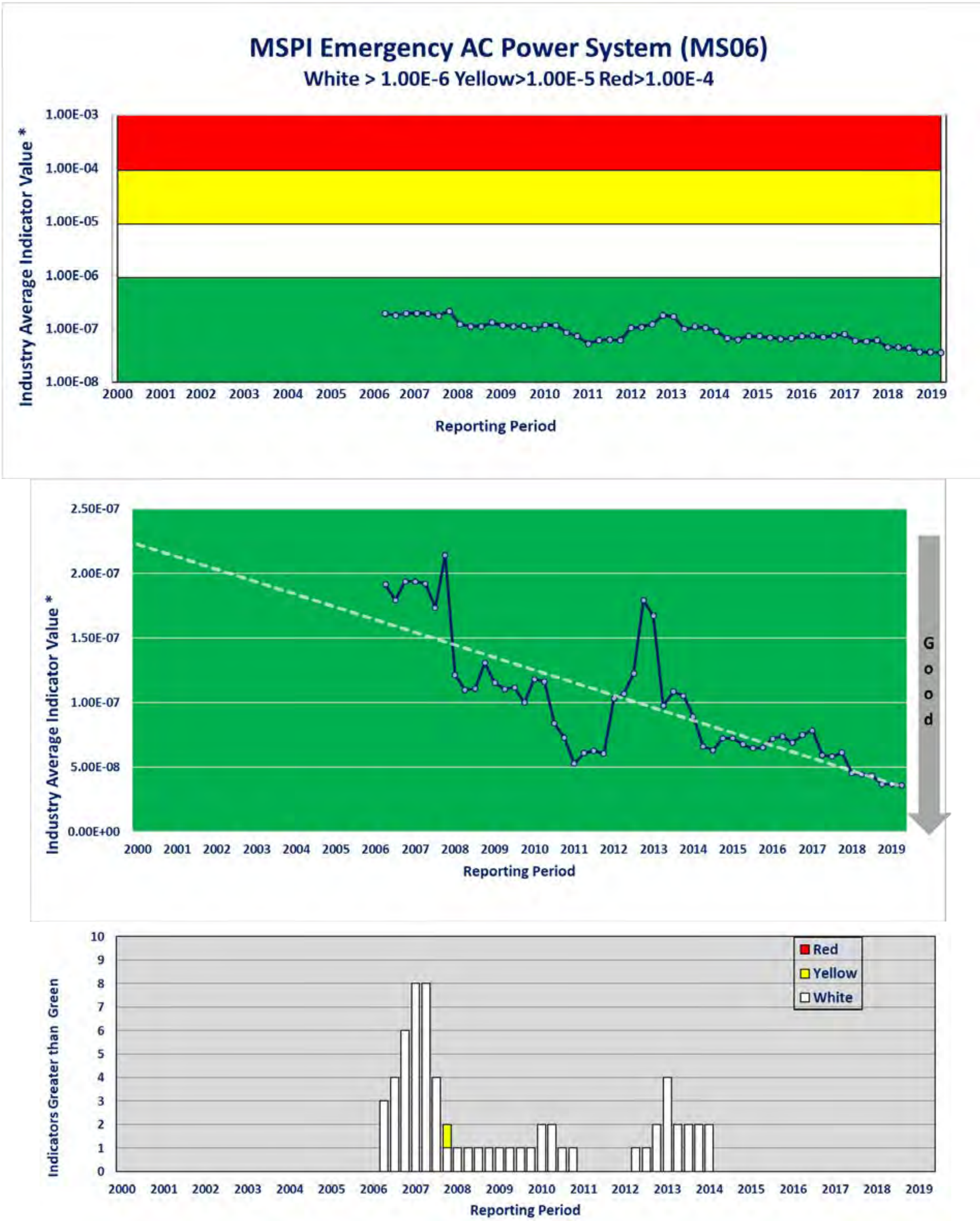
**Figure B4 – Unplanned Scrams with Complications (IE04)**




**Safety System Functional Failures (MS05)**—The number of events or conditions that alone prevented, or could have prevented, the fulfillment of the safety function of structures or systems in the previous four quarters.

**Figure B5 – Safety System Functional Failures (MS05)**

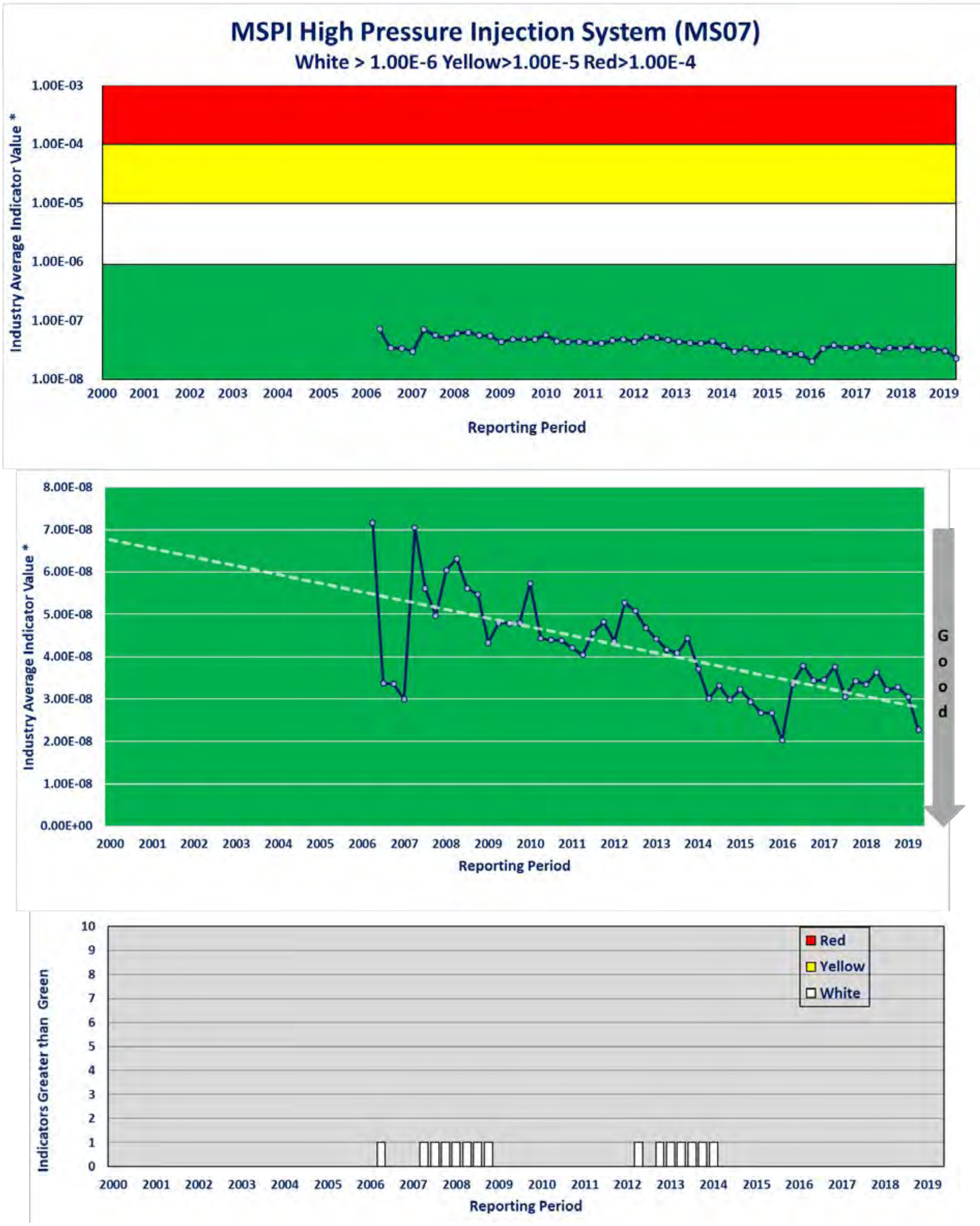



**Emergency AC Power Systems (MS06)**—The sum of the unavailability of the emergency AC power plus the unreliability for the emergency AC power system during the previous 12 quarters. This indicator was started in 2006.

**Figure B6 – MSPI Emergency AC Power System (MS06)**

* - MSPI values can be negative. For the purposes of the industry average calculation, negative MSPI values were set to zero.

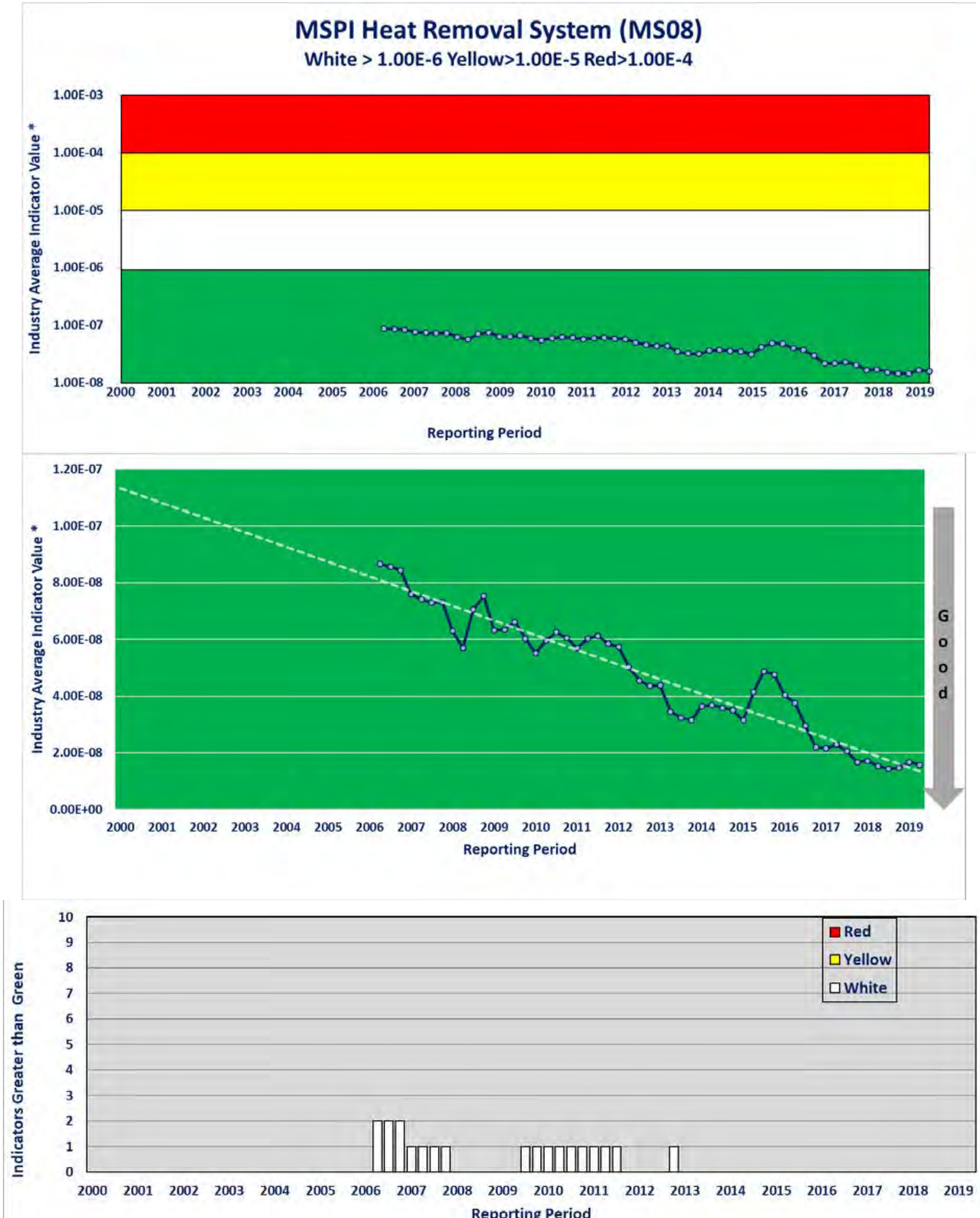
 




**High Pressure Injection Systems (MS07)**—The sum of the unavailability of the high pressure injection system plus the unreliability for the high pressure injection system during the previous 12 quarters. This indicator was started in 2006.

**Figure B7 – MSPI High Pressure Injection System (MS07)**

* - MSPI values can be negative. For the purposes of the industry average calculation, negative MSPI values were set to zero.

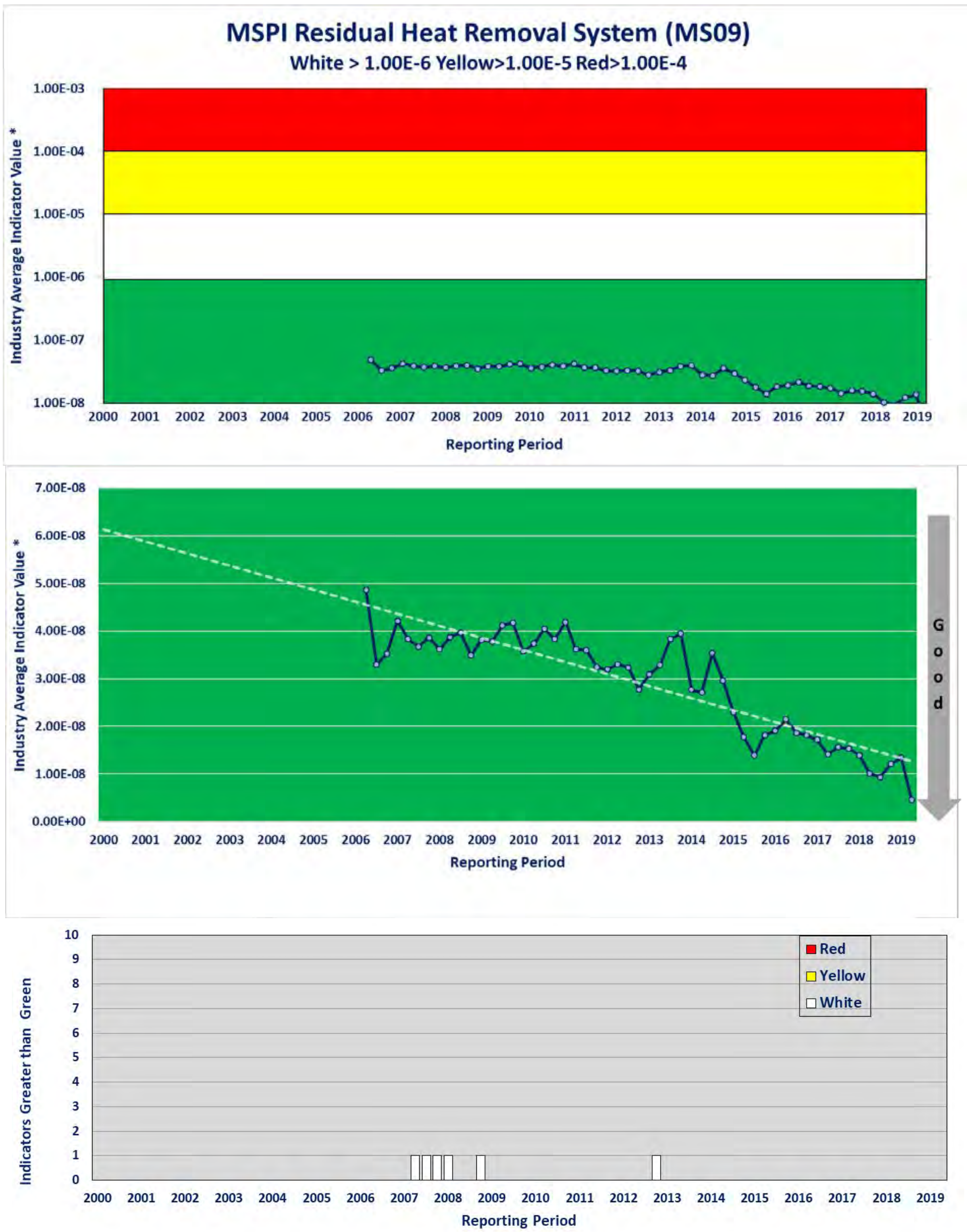



**Heat Removal Systems (MS08)**—The sum of the unavailability of the heat removal system plus the unreliability for the heat removal system during the previous 12 quarters. This indicator was started in 2006.

**Figure B8 – MSPI Heat Removal System (MS08)**

* - MSPI values can be negative. For the purposes of the industry average calculation, negative MSPI values were set to zero.

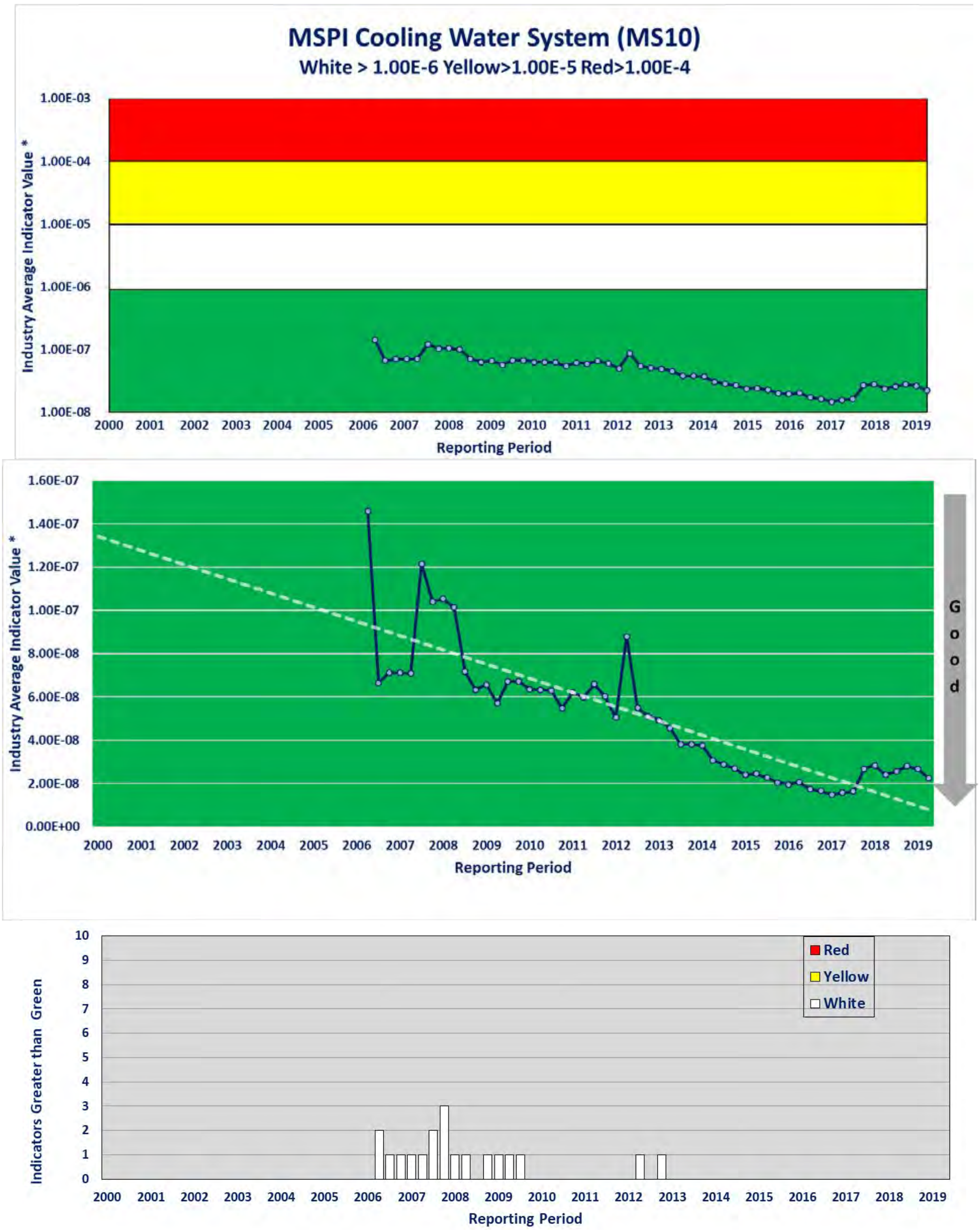



**Residual Heat Removal Systems (MS09)**—The sum of the unavailability of the residual heat removal system plus the unreliability for the residual heat removal system during the previous 12 quarters. This indicator was started in 2006.

**Figure B9 – MSPI Residual Heat Removal System (MS09)**

* - MSPI values can be negative. For the purposes of the industry average calculation, negative MSPI values were set to zero.

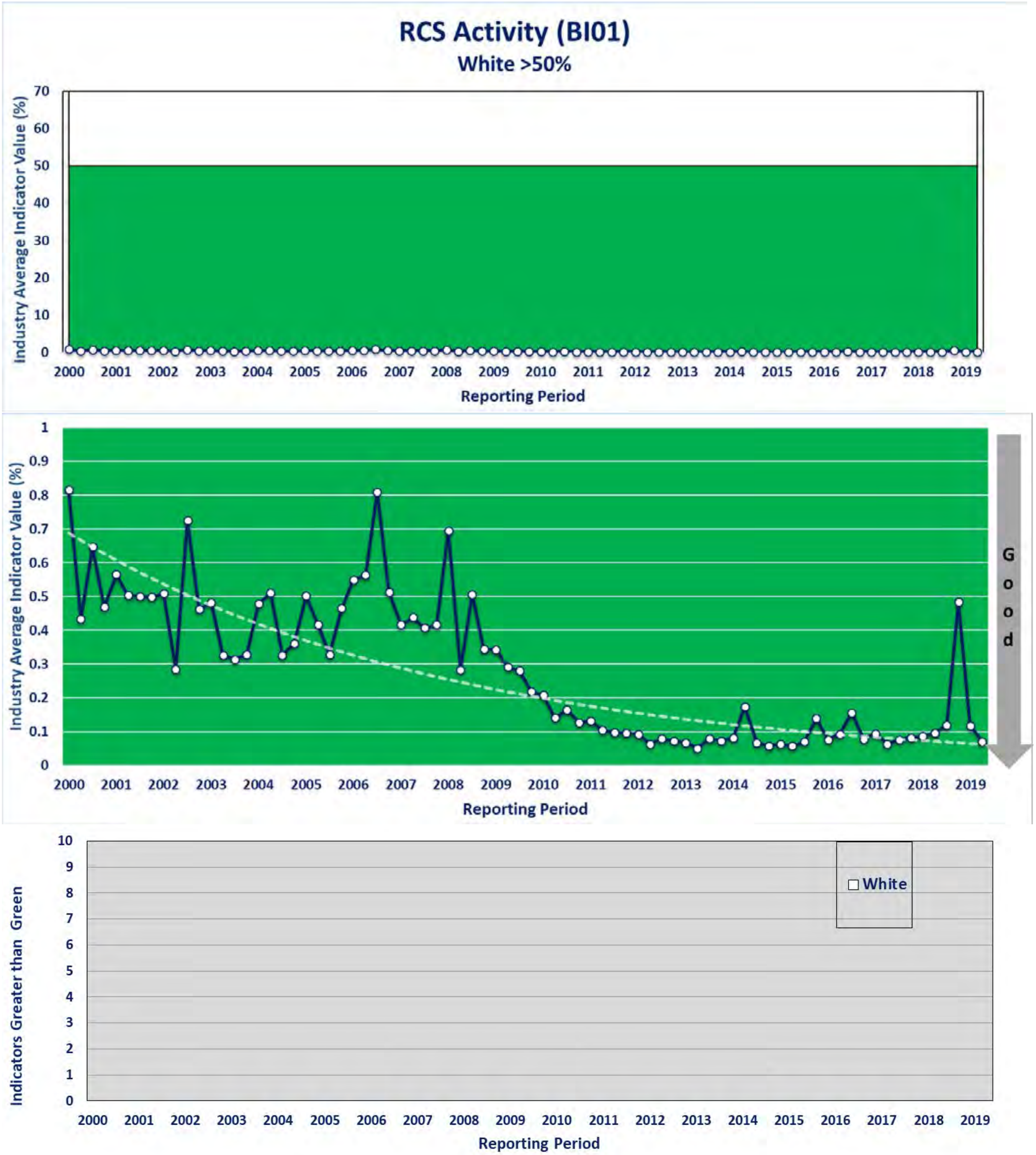



**Cooling Water Systems (MS10)** —The sum of the unavailability of cooling water systems plus the unreliability for the cooling water systems during the previous 12 quarters. This indicator was started in 2006.

**Figure B10 – MSPI Cooling Water System (MS10)**

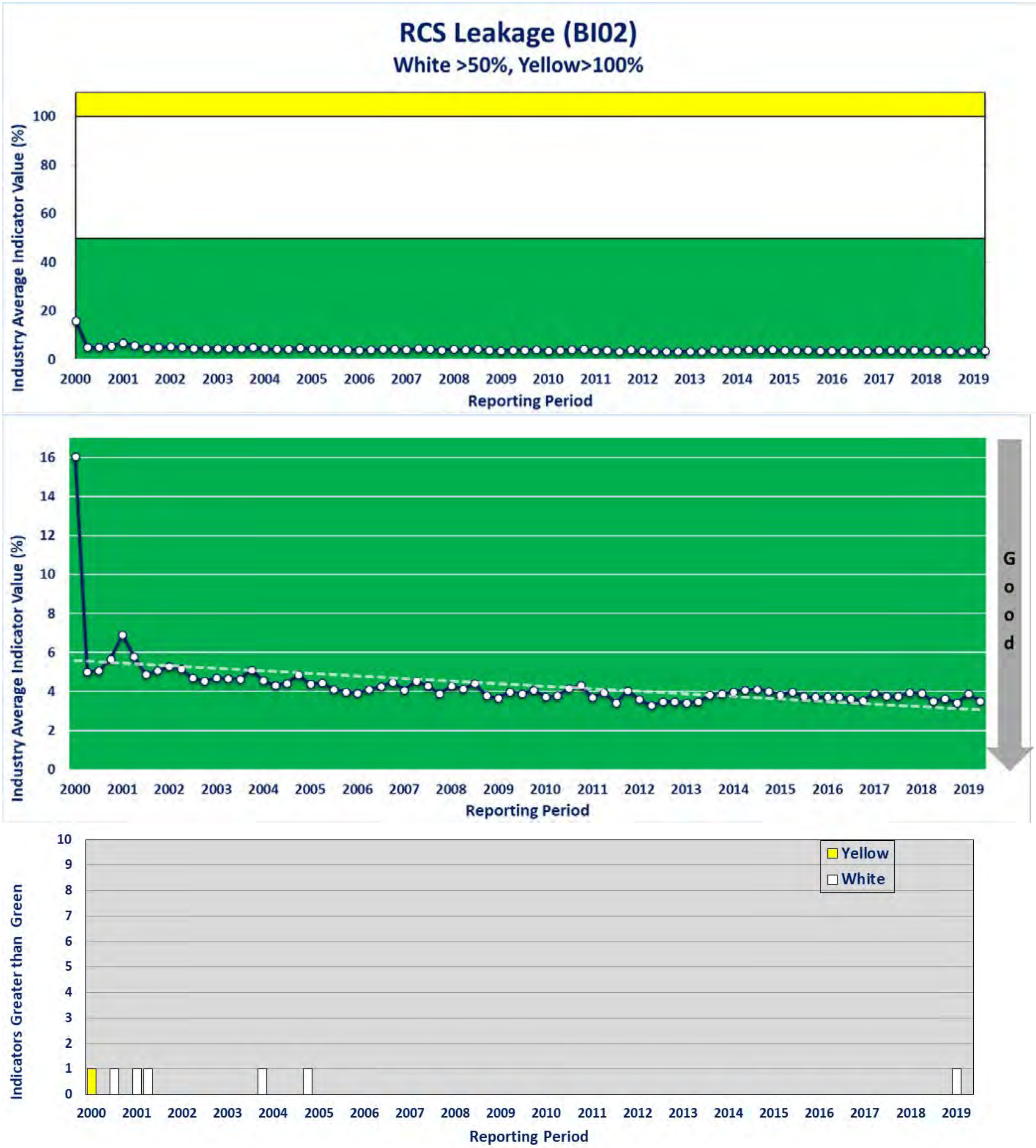
* - MSPI values can be negative. For the purposes of the industry average calculation, negative MSPI values were set to zero.




**Reactor Coolant System (RCS) Specific Activity (BI01)** – The maximum monthly RCS activity in microcuries per gram dose equivalent Iodine-131 per the technical specifications, expressed as a percentage of the technical specification limit.

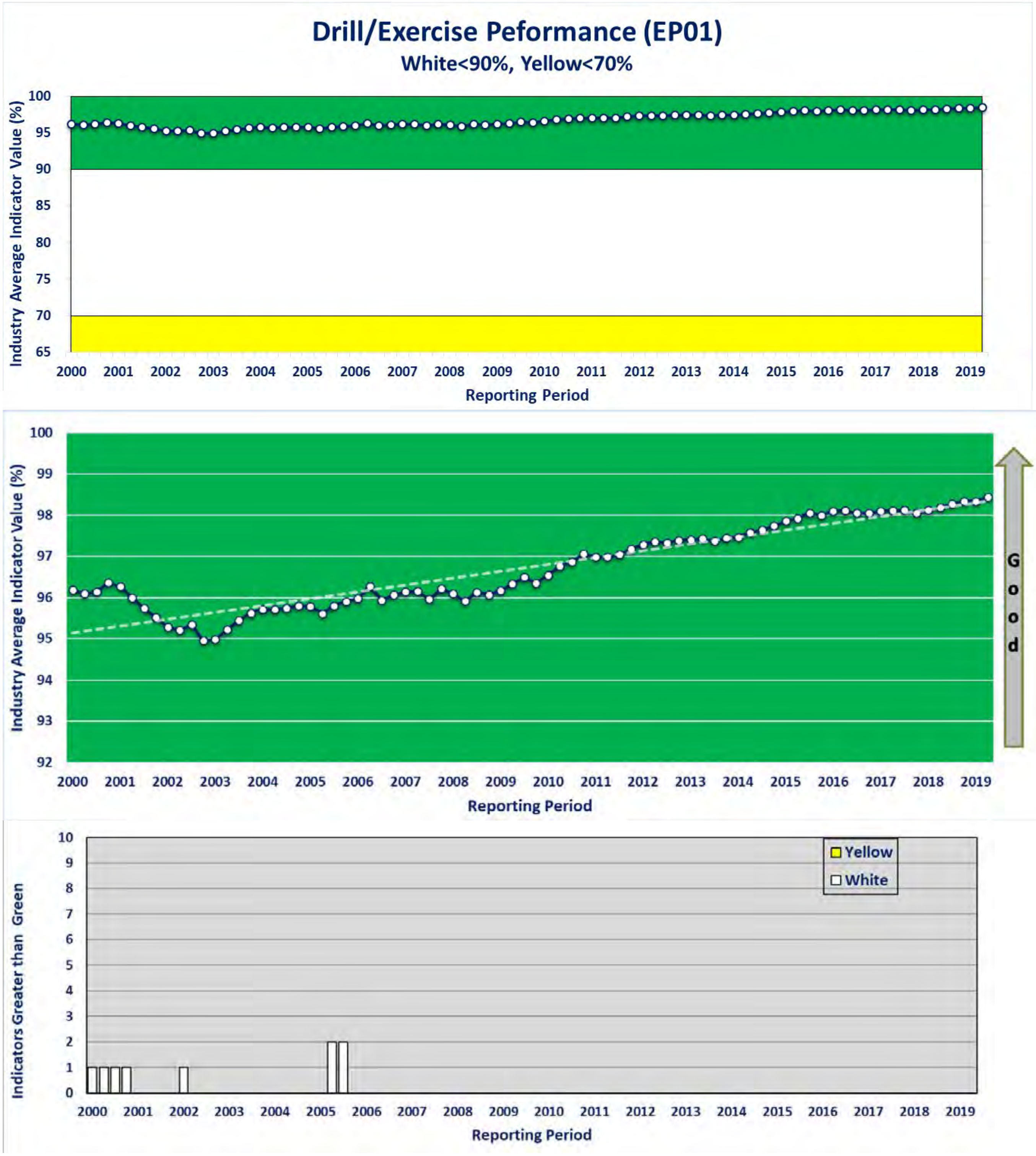
**Figure B11 – RCS Activity (BI01)**




**Reactor Coolant System (RCS) Leakage (BI02)** – The maximum RCS identified Leakage in gallons per minute each month as defined in technical specifications, expressed as a percentage of the technical specification limit.

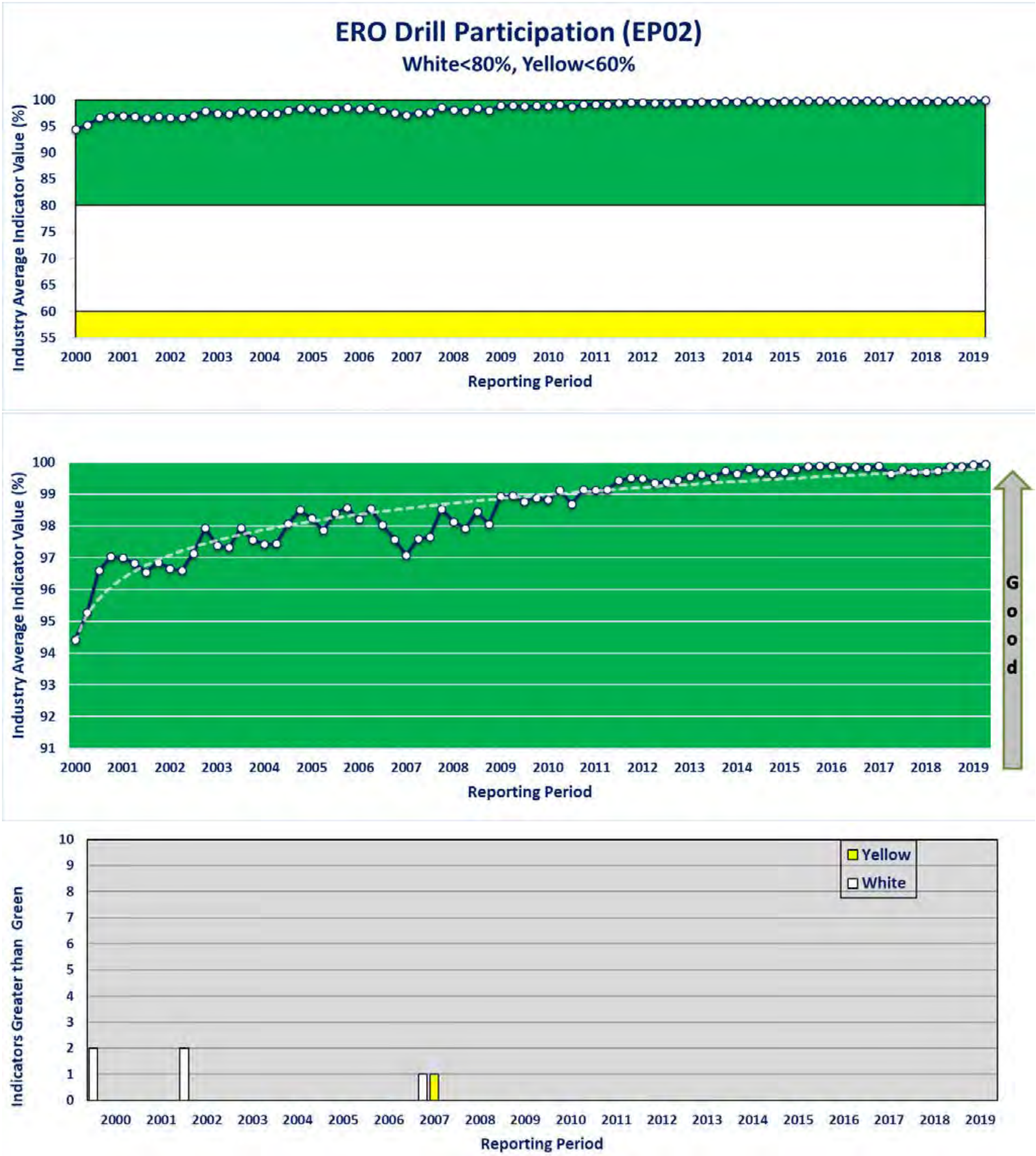
**Figure B12 – RCS Leakage (BI02)**



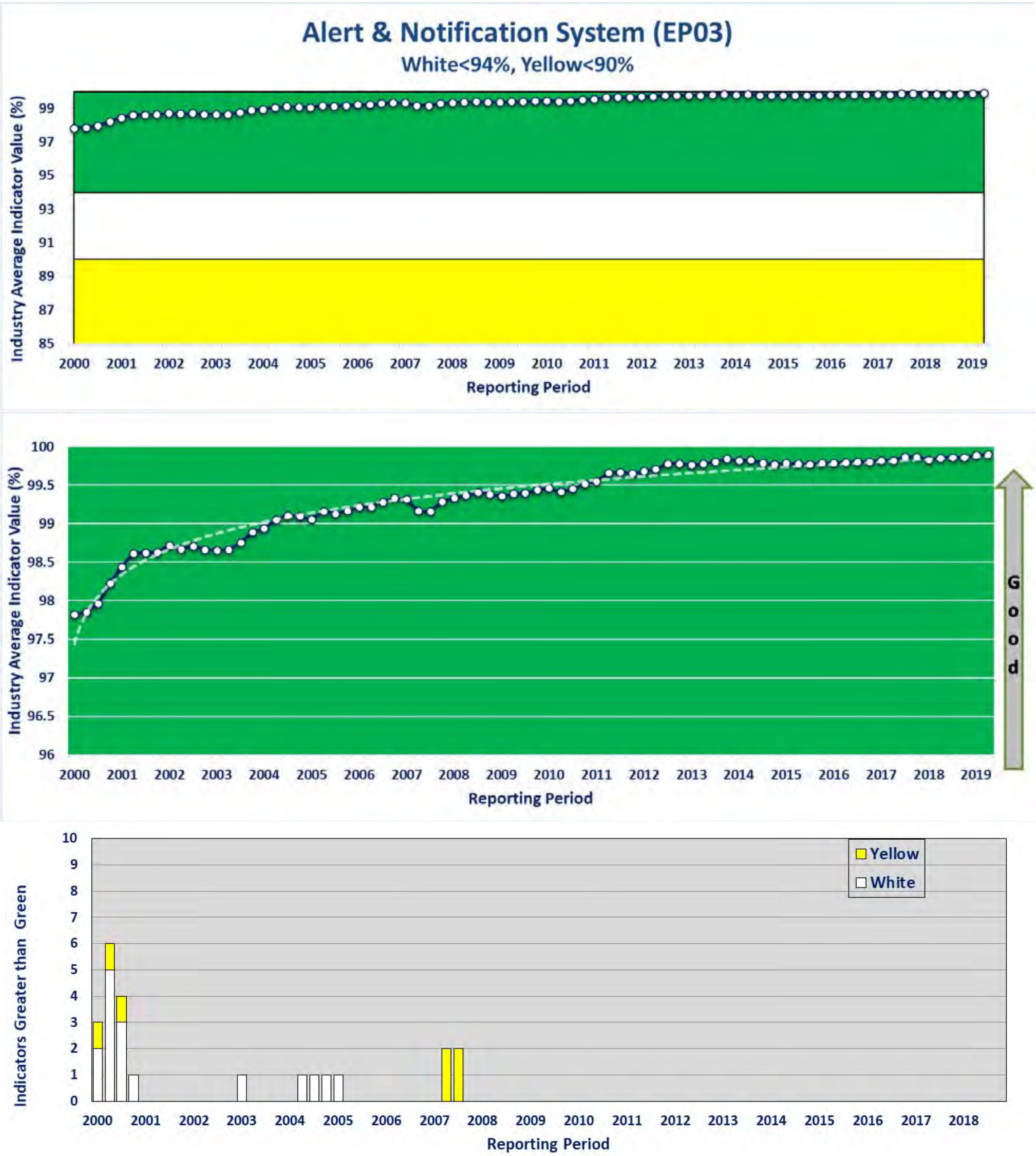

**Drill/Exercise Performance (EP01)**—The percentage of all drill, exercise, and actual opportunities that were performed timely and accurately during the previous eight quarters.

**Figure B13 – Drill/Exercise Performance (EP01)**




**Emergency Response Organization (ERO) Drill Participation (EP02)**—The percentage of key ERO members that have participated in a drill, exercise, or actual event during the previous eight quarters, as measured on the last calendar day of the quarter.

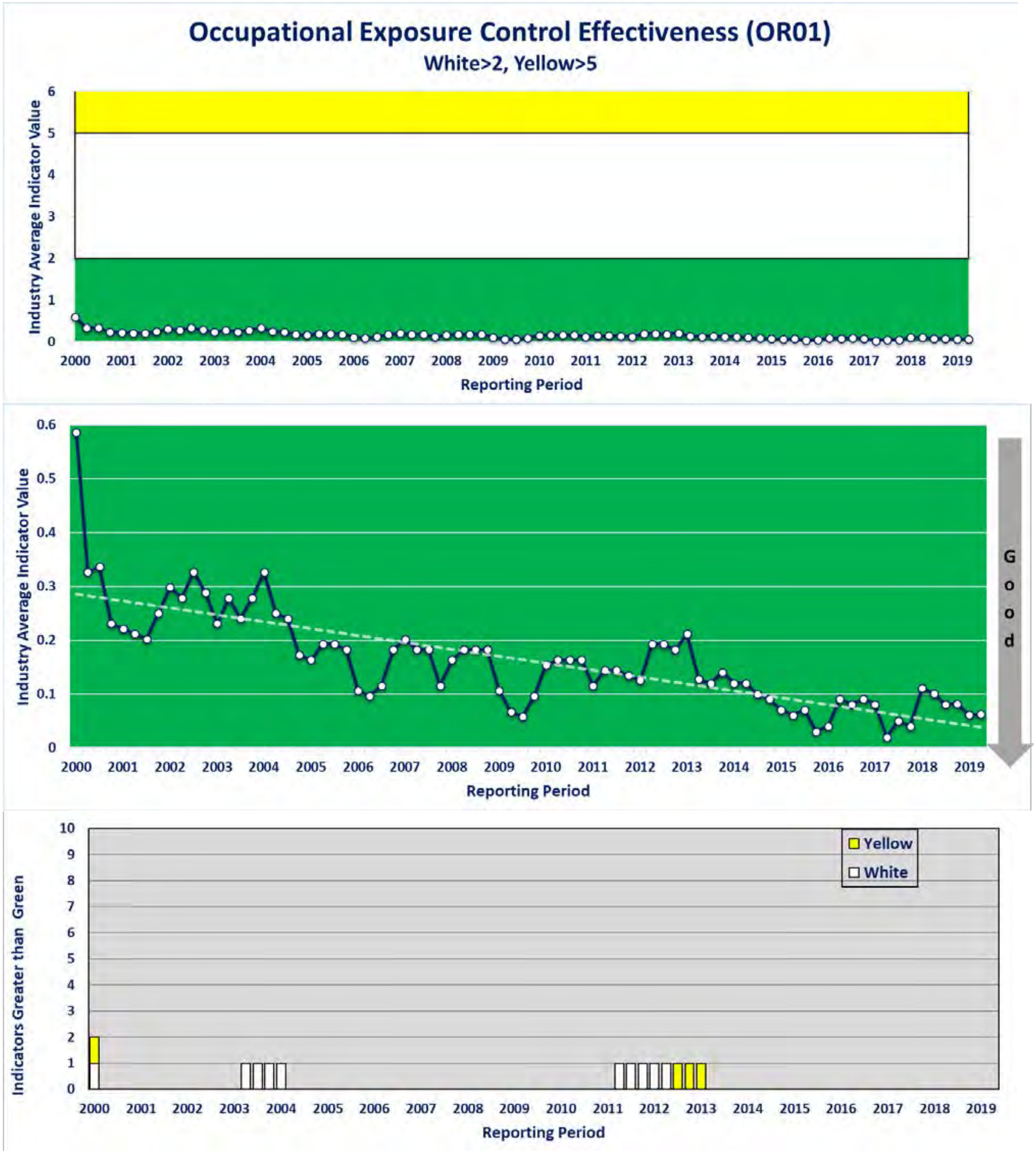
**Figure B14 – ERO Drill Participation (EP02)**




**Alert and Notification System Reliability (EP03)**—The percentage of ANS sirens that are capable of performing their function, as measured by periodic siren testing during the previous 12 months. Periodic tests are the regularly scheduled tests that are conducted to actually test the ability of the sirens to perform their function (e.g., silent, growl, siren sound test).

**Figure B15 – Alert & Notification System (EP03)**

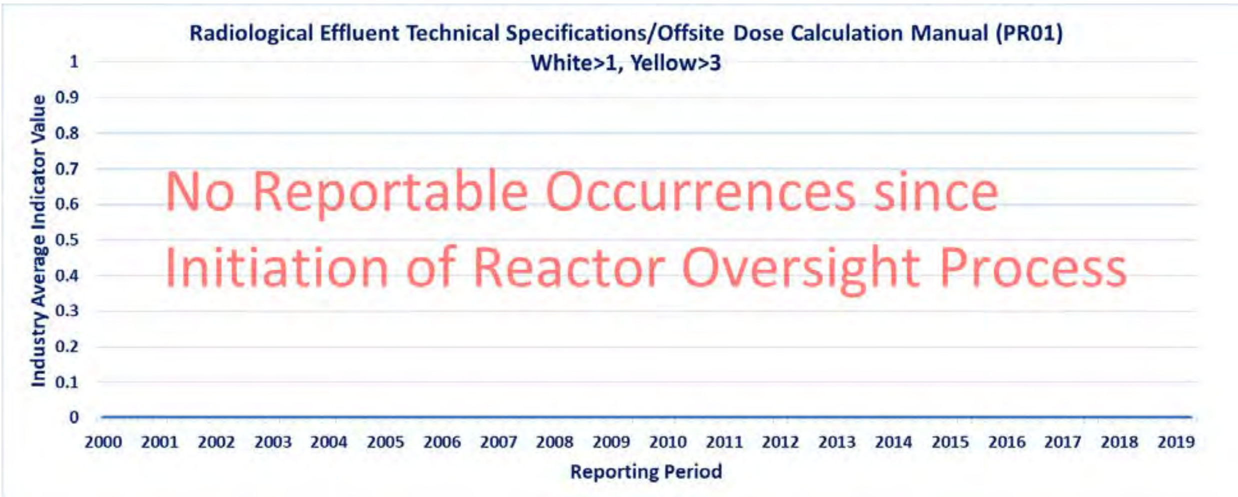
 




**Occupational Exposure Control Effectiveness (OR01)**—The PI for this cornerstone is the sum of the following:

- Technical specification high radiation area occurrences
- Very high radiation area occurrences
- Unintended exposure occurrences

**Figure B16 – Occupational Exposure Control Effectiveness (OR01)**




**Radiological Effluent Technical Specifications/Offsite Dose Calculation Manual (RETSs/ODCM) (PR01)**—Radiological effluent release occurrences per reactor unit that exceed the values listed below:

- Liquid Effluents
  - Whole Body—1.5 millirems per quarter (mrem/qtr)
  - Organ—5 mrem/qtr
- Gaseous Effluents
  - Gamma Dose—5 millirads per quarter (mrad/qtr)
  - Beta Dose—10 mrad/qtr
  - Organ Doses from I-131, iodine-133, tritium, & particulates—7.5 mrem/qtr

**Figure B17 – RETS/ODCM (PR01)**

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