The Inspector General's report on Nuclear Safety and Radiation Protection

2020
















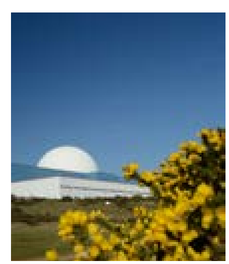


EDF

FOREWORD

This report, written for the Chairman of EDF, gives my assessment of nuclear safety and radiation protection within the EDF Group.

The report is also intended for all those in the company who contribute in some way to nuclear safety and radiation protection through their day-to-day actions and decisions. It will have achieved its purpose if it inspires further reflection and debate.

It also aims at identifying any early warning signs and recommending areas for improvement. It therefore focuses on difficulties and weaknesses rather than strengths and progress. This may seem unfair to those who spare no effort on a daily basis to ensure that complex, demanding nuclear power facilities are designed, built and operated safely.

This report does not set out to be exhaustive. The number and length of the chapters are deliberately kept to a minimum to highlight the key points.

This report covers all matters within the EDF Group that contribute in any way to the safety of nuclear activities. This particularly concerns the fields of engineering and operations, in both France and the United Kingdom. It is, however, important to avoid making any hasty comparisons between these two fleets as the reactor technologies, fleet sizes and regulatory contexts differ.

My assessment is based on observations made and information gathered from workers in the field, or during visits to plants and meetings with the main stakeholders: staff representatives, members of the medical profession, contractors, etc. The report also takes into account discussions with WANO[1] and safety authorities.

The travel restrictions imposed during the Covid-19 pandemic in 2020 greatly disrupted the IGSNR programme of site visits. All the visits in France that were cancelled owing to lockdown were carried out at a later date. The scheduled visits of UK sites were carried out by video-conference, with only the British IGSNR member physically present. These conditions thus moderate the scope of my assessment of the UK fleet.

I would like to thank all those I met for their unstinting support and candour, not to mention the breadth of our discussions. Their openness, which determines the relevance of this report, is fully in keeping with the spirit of a strong nuclear safety culture.

I would also like to thank Jean-Michel Fourment, Bertrand de L'Epinois, Stephen Preece and Jean-Paul Joly who have been relentless in their efforts, particularly in drafting this report. I would like to give a special mention to André Palu who left the team in 2020. Like last year, the chapter on Framatome has been written by its Inspector General, Alain Payement.

This document is available to the public in both French and English on the EDF website (*www.edf.fr*).

EDF Group Inspector General
for Nuclear Safety and Radiation Protection

François de Lastic
Paris, 25 January 2021

[1] *World Association of Nuclear Operators*

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Blayais nuclear power plant

My view

THE SITUATION IN 2020

During the Covid-19 crisis, all the world's nuclear operators were able to make the necessary adaptations and continue producing the required electricity.

In France, the economic recovery plan introduced in response to the crisis will devote a modest but symbolic share to the nuclear industry (€470 million of the total €100 billion announced), which is considered significant. The long-term energy plan, debated for several years and finally adopted in April 2020, sets out the conditions for the continued operation of existing reactors but has not yet given any decision on their replacement. In December 2020 at Le Creusot plant, the French President clearly stated that nuclear energy should remain a pillar of its future energy policy.

A joint decision by the Minister for Ecological Transition and the Nuclear Safety Authority (ASN) is paving the way for targeted exemptions allowing recycling of very low-level metal waste from nuclear facilities. This will lead to savings on raw materials and reduce the required waste storage capacity.

The UK aims to achieve net zero carbon emissions by 2050. Pending the publication of its Energy White Paper, the UK government published in November 2020 its 10-point plan for a green industrial revolution. It confirms that nuclear energy will play an essential role in this plan.

THE EDF GROUP

Both fleets have handled the Covid-19 lockdowns very well, and nuclear safety has remained a central priority (*see Chapter 2*). The pandemic has once again demonstrated the commitment of staff and the ability of the company to deal with a crisis.

It has brought about some simplification in the organisation of work and helped prioritise activities. An analysis is currently underway to assess which measures should be continued. In addition, plants will have to catch up with maintenance and training activities that have been postponed.

Staff are proud of having kept going and do not understand the cut-backs specified in the Mimosa plan to make up for the company's loss of revenue. The ARENH[1] reform has entered a more intense phase of negotiations. This mechanism gives other electricity suppliers access to a significant proportion of the energy produced by EDF's nuclear power plants at a very low price. There are various inconsistencies resulting from the ARENH mechanism, leading to significant restriction of EDF's capability to invest in existing facilities and in preparation for the future.

The ARENH reform coincides with the Hercule project, a planned major reorganisation of the Group, which continues to cause a great deal of apprehension. From a strictly nuclear safety perspective, I believe it is more important than ever that the future organisation, however it is structured, maintains consistency and synergies between the nuclear functions across the French and UK fleets, the engineering divisions, R&D, etc. I would add that it is equally important not to lose sight of the strong interfaces between the hydroelectric and the nuclear sectors at EDF in areas such as: heat sinks, operating reserves, skills (meteorology, hydrology, geosciences), etc.

In December 2019, following the report by Jean-Martin Folz on the issues facing the nuclear industry, EDF launched the *plan excell* that aims to achieve the highest possible level of rigour, quality and excellence. With a budget of €100 M, its execution is being overseen by an executive committee member who reports directly to the Chairman. Ten transformation projects have started, involving a great many consultations and visits both within and outside the Group. In October 2020, 25 commitments were made that must be completed by mid-2021. Most will benefit nuclear safety, including those concerning project management, skills, partnerships with contractors, and the quality of work.

THE FRENCH PLANTS

Following Tricastin in 2019, a second 4th ten-yearly outage (VD4) of a 900 MWe reactor was conducted at Bugey in 2020 (*see Chapter 8*). Their success was based on forward planning, breaking down

[1] *Regulated access to incumbent nuclear electricity, established by French law in 2010*

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barriers within plant departments, significant involvement of the Nuclear fleet engineering, decommissioning & environment division (DIPDE), and effective management by the Fleet upgrade programme (*Grand carénage*) and the DPN. These first VD4 900 outages mark a significant step forward in improving the nuclear safety of these reactors, not to mention a considerable increase in the workload (engineering and industrial), which I have observed for several years (*see Issues requiring attention*).

Examining a fuel element - Flamanville 3

Flamanville 3 progressed in 2020, with completion of the hot functional tests and arrival of the fuel. I note the beneficial effects of the project and plant staff who are now organised as a joint team. I also note the progress made with the technical topics, such as the repairs on the main steam lines. Numerous subjects still need to be dealt with, such as corrosion of the rising stems in the pressuriser relief valve control systems, performance of CCWS/ESWS heat exchangers, thermal and mechanical fatigue predictions of some components, qualification of equipment for accident conditions, etc. I call on the Operator to complete the preparatory work, in particular in terms of resources (operation, maintenance, spare parts, operating documentation, etc.) and to address the maintenance backlog that built up during assembly and testing. The right level of integration into the fleet also needs to be determined for this reactor.

DECOMMISSIONING AND WASTE

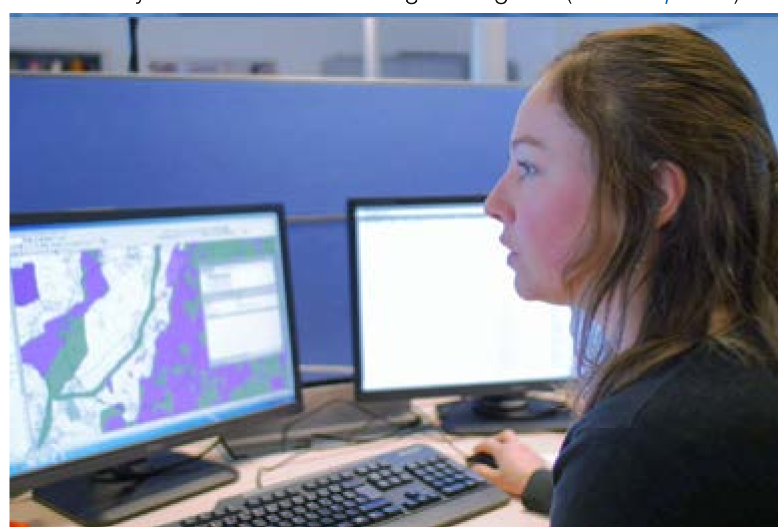
The operation of the two pressurised water reactors at Fessenheim, which were permanently withdrawn from service in February and June 2020, remained satisfactory to the end. The future of practically all staff is known. Dismantling, for which the authorisation application was submitted at the end of 2020, should take place between 2025 and 2041. This dismantling schedule is ambitious but realistic, according to the international experience on this type of reactor. In the meantime, the pre-dismantling phase has started in conjunction with the DPN and the Decommissioning & waste directorate (DP2D), with the aim to reach a state in which the facilities can be decommissioned. This phase determines the level of difficulty of subsequent dismantling operations, especially in terms of radiation protection measures.

The centralised fuel storage pool project is progressing satisfactorily. This project is important for long-term storage of spent MOX fuel.

I note that the building of a decommissioning demonstrator for UNGG[2] reactors has begun. This is a good initiative, as this type of reactor is much more difficult to decommission than pressurised water reactors.

THE ENGINEERING DIVISIONS

I repeat my 2019 warning about the very heavy workload on the engineering divisions, both in terms of new-build projects and modifications to existing reactors such as during the 10-yearly outages (*see Issues requiring attention*). This leads to the significant use of contractors. The scope of such practices must be controlled to avoid running any risks in quality, staff motivation and more broadly EDF's ability to fulfil its architect-engineering role (*see Chapter 9*).



Engineer at the DIPDE

[2] *Gas-cooled graphite-moderated reactor*

The French fleet's Design Authority[3], within the DIPDE, is now fully operational and playing an important role in the knowledge, compliance and development of reactor design.

FRAMATOME

To prevent the recurrence of the quality issues encountered over the past few years (i.e. welds at Flamanville 3, stress-relieving heat treatment processes on steam generator welds), Framatome implemented the 'Excell in Quality' plan in early 2020. This is based on the Group's *plan excell* and includes programmes for the industrial standardisation and stabilisation of tools and processes used to manufacture large components.

Further, I believe staff transfers between EDF and Framatome are needed to improve mutual understanding and trust.

PREPARATION FOR THE FUTURE

I visited several EDF R&D centres in 2020 and appreciated both the quality of their facilities, and the skills and commitment of those involved. I was shown some impressive experiments. R&D is without doubt one of the Group's major assets for preparing for the service life of the existing fleet and future reactors. In a context of increased financial constraints, it is important to maintain R&D activities.

The EPR 2 studies are progressing, with finalisation of the preliminary safety report and the tender documents in 2021 (*see Chapter 9*).

The feasibility phase of the NUWARD™ SMR[4] project, which involves EDF, TechnicAtome, the CEA and Naval Group, has been completed and the conceptual design phase has begun. The objective of NUWARD™ is innovation, modularity and simpler, standardised design across a series of reactors. Together with EPR 2, it has much to offer in preparing for the future.

THE UK FLEET

The two Hunterston B reactors resumed production in 2020 after a long shutdown. A great deal of work was carried out to assess the risks posed by the identification of cracking in some graphite moderator bricks. Additionally, EDF Energy have decided to withdraw the Hunterston B and Hinkley Point B reactors from service no later than January and July 2022 respectively. In the meantime, they will be subject to authorisation from the nuclear safety authority (Office for Nuclear Regulation, ONR), based on ongoing inspection of the graphite bricks.

The clarity provided by this decision on reactor lifetimes is an important factor for nuclear safety, especially as the imminence of the shutdown dates will mean there is no need to look for further margins within the safety cases of these reactors. Their final shutdown will mark the beginning of a major transition for the UK fleet (*see Issues requiring attention*).

The two Dungeness B reactors, which have been shut down for more than two years while major repair work is carried out, should restart in early 2021. Restarting after such a long period requires specific attention due to the teams' loss of knowledge and practical skills. They must therefore prepare for this eventuality.

Hinkley Point C construction site

The Sizewell B pressurised water reactor (PWR) is 25 years old. In the transitional period that the UK fleet is due to undergo, it will be necessary to ensure that all the resources needed to keep it fully operational are available. Cooperation with other PWR fleets should be strengthened.

EPR PROJECTS IN THE UNITED KINGDOM

During the first lockdown, Hinkley Point C (HPC) was one of the few construction sites in the UK to continue working, albeit on a somewhat reduced scale. Construction targets continue to be met, including the concrete pour for the Reactor 2 raft. A forthcoming challenge will be starting the mechanical, electrical and HVAC (MEH) work, scheduled for late-2021. This will be dependent on the timely supply of this equipment to site, consistency of the engineering studies and contracts, and adaptation of the construction site, the nature of which will change. The project is preparing for this change, with the creation of an on-site engineering team combining the project team and the French engineering centres (Joint Design Office) (*see Chapter 9*).

[3] *Organisation which, according to INSAG 19, "is responsible for ensuring that the knowledge base is established, has been preserved and is expanded with experience."*
[4] *Small Modular Reactor*

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The planning applications for two EPRs at Sizewell C were submitted in 2020. The financing, which is currently being considered, could include an element of public funding.

HUMAN RESOURCES

I have noticed that some jobs in the nuclear industry are less attractive than in the past. They are adversely affected by the complexity of the processes and organisations, and the resulting loss of direction and feeling of inefficiency is frequently off-putting. The people I met also want more positive communication on the nuclear industry, which seems to have been the case towards the end of the year.

In 2020, EDF SA launched the TAMA experiment ("working differently, managing differently"). I believe its objectives are relevant, but this must not be reduced simply to the widespread introduction of working from home. This is not suitable for all jobs; its consequences on team cohesion and 'cross-fertilisation' through frequent interaction should be examined from a broader perspective (*see Chapter 2*).

More generally, I support the concept of greater accountability as required in the DPN's Start 2025 project (*see Chapter 3*). I note that methods such as Evolean and similar approaches are viewed positively in teams that have already been working on trust, accountability and autonomy.

MAIN RESULTS FOR 2020

The results for both fleets (*see Chapters 1* and *4*) are improving overall, although given the unprecedented nature of the year due to Covid-19, the comparisons with previous results are not straightforward. Nevertheless, the lockdown has not affected vigilance in nuclear safety.

In France, following a negative trend in 2019, the nuclear safety indicators improved in 2020. The number of automatic reactor trips has never been so low (14). Once the operating time has been taken into account, this result is the best ever achieved. The number of non-compliances with technical specifications has reduced but remains high. Fire prevention indicators declined slightly in 2020, while maintaining the positive overall trend of the past few years (*see Chapter 6*).

I appreciate the changes undertaken by the DPN to better take into account international standards and best practices; this was recognised by WANO during the EDF SA Corporate Peer Review follow-up.

Industrial safety results are also improving, with an overall LTIR[5] of 2.2 (2.4 in 2019) for the DPN (EDF and contract partners). The radiation dose level indicators are improving, with a significant reduction in the number of workers who received a dose of more than 10 millisievert. However, I note numerous cases of skin contamination, repeat events associated with radiography work, and breach of the access rules to red radiation-controlled areas. The radiation protection culture seems to be weakening.

Turbine rotors - Gravelines nuclear power plant

In the UK, the industrial safety and radiation protection results are good as usual, and the turnaround in nuclear safety results that began in 2019 is continuing. The satisfactory results include a significant decrease in automatic and manual reactor trips, as well as in plant alignment errors. As in France, the weakest area is still non-compliance with technical specifications.

Over the past few years, I have noticed both fleets having problems with detecting early signs of when sites are in decline (*see Chapter 3*). I believe senior management needs to make an effort to identify early warning signals of such situations and to establish a support strategy for these sites.

INDEPENDENT OVERSIGHT IS IMPROVING

In France, I note the good technical level of the plant safety engineers. A few years ago, these were often new young recruits, but their recruitment is now more diversified. The practice of having daily face-to-face meetings with shift managers is robust. However, safety engineers spend a great deal of time on the event reporting process, rather than reviewing operational decisions and carrying out in-depth analyses.

[5] *The lost-time injury rate (LTIR) or "accident rate defined as the number of industrial accidents leading to sick leave per million hours worked" replaced the accident rate (Tf) within EDF SA in 2019.*

The content of the recommendations, issued by the DPN's Nuclear Inspectorate (IN), shows that its investigations are thorough. However, the uptake of these recommendations by the sites is insufficient. Since 2020, the IN has also been employed as an independent body for oversight of the DPN senior management, which I believe is a sensible decision.

In early 2020, the work carried out by the DIPNN on its independent oversight team led to the definition of principles, which were based on those of the operations functions but adapted for the engineering functions. They are relevant, but their implementation, planned for the first half of 2020, has been postponed due to the pandemic.

The internal authorisation system for major modifications, in place since July 2019, is operating satisfactorily. This process is positive by making the Operator more accountable. It generates a considerable but acceptable workload, in particular for the Nuclear fleet engineering, decommissioning & environment division (DIPDE) and the Operations engineering unit (UNIE).

In the UK, I am pleased with the robustness and positioning of the Independent Nuclear Assurance department (INA). It has the full confidence of the Office for Nuclear Regulation (ONR), which asked INA to carry out inspections on its behalf during the Covid-19 crisis. Ensuring this credibility is maintained requires the continued recruitment of experienced staff, which is not always easy.

At Framatome, independent nuclear safety oversight is operational in the fuel fabrication plant in Romans-sur-Isère. An oversight function is progressing within the Engineering and technical directorate (DTI). The pace of its deployment in other Framatome divisions must be accelerated.

RELATIONS WITH THE NUCLEAR REGULATORS

In France, relations with the nuclear regulator (ASN) are well-balanced when it comes to managing issues in the short term, but there is some concern for the medium to long term. In spite of the technical quality of some examinations, the regulator's tendency to inflate requests overloads EDF's resources, adversely affects prioritisation and increases general complexity.

In the UK, the ONR's confidence in EDF Energy Nuclear Generation seems to have been restored to a good level, after having been eroded. Relations remain good between the ONR and Hinkley Point C.

Hinkley Point B nuclear power plant

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ISSUES REQUIRING ATTENTION

ACCOUNTABILITY AND SIMPLIFICATION

On a daily basis and at all levels, the nuclear safety culture is robust in both the operating fleets and in the engineering divisions. It underpins decision-making and has proved to be particularly robust during emergency situations, as has been demonstrated by the behaviour of staff during the Covid-19 pandemic.

The price of the high level of requirements for nuclear activities is that every situation, every problem and every non-conformity identified results in new action plans, processes, organisations, etc. It is implicitly assumed that if a rule is correct and is applied, nuclear safety will be assured. The same logic is behind the increased number of demands by the nuclear regulator. Meeting their requirements has gradually come to be considered as a guarantee of nuclear safety. Taken to the extreme, this could lead to a mechanistic working environment limited to compliance with internal or external rules. And the more comfortable the environment, the more dangerous it becomes!

All this increases complexity, deflects attention and ends up with people being less accountable. Yet one of the key nuclear safety culture principles is individual accountability (*see Chapter 3*).

It is essential that the Operator retain its primary responsibility for nuclear safety. This requires that everyone, at their own level, feel accountable for their own actions, which must always be underpinned by a strong awareness and management of the risks specific to the nuclear industry.

This sense of accountability is inextricably linked to a good performance culture. Although this is not enough on its own, the commitment of management is essential: they must create conditions so that everyone feels accountable, and can prioritise and simplify what is within their remit.

SKILLS: ENCOURAGING GREATER MANAGERIAL INVOLVEMENT AND REVITALISING CAREER PATHS

Nuclear safety relies strongly on the skills within a team (*see Chapter 5*).

In France, the appeal of the EDF Group enabled it to undertake a significant renewal of its workforce a few years ago, recruiting a great many new, young nuclear professionals. However, it is currently suffering from the fading appeal of technical jobs, together with a loss of interest in the nuclear industry. From this standpoint, the launch of a new reactor programme would be a pivotal decision.

In the current situation, recruitment requirements are limited, but it is important to maintain a significant volume of new recruits as the management of human resources is a long-term process and cannot react easily to sudden changes.

It is also necessary to establish attractive career paths, developing people's skills and fostering their motivation. I also note that advanced planning of jobs and skills (the much talked-about "GPEC" in France) is occasionally reduced simply to staff management, with skills and forward planning often forgotten.

The current situation - low influx of recruits and staff who are generally young and inexperienced - justifiably leads to prioritisation of short-term needs and lengthening of the time staff are in their jobs. However, it is important not to lose sight of the long-term need to have staff with broad experience, which can only be achieved through job diversity. As well as lengthening the time staff are in their jobs, I recommend a more proactive approach to mobility between the two nuclear fleets, between the plants, the engineering divisions and R&D, and also between EDF and Framatome.

The Group has robust training resources, however, all training needs to be supplemented by practice in the field. The Group has several advantages here, as EDF SA employs many young people on work-study programmes and EDF Energy recruits much of its workforce via apprenticeships. With the current low influx in France, it is a good time to inject fresh impetus into mentoring. This could be more difficult during periods of high recruitment if not enough qualified instructors are available.

Solid practical work and mentoring are necessary for acquiring skills. I think that in France, in order to boost the experience and confidence of the many young people in the plant maintenance teams and engineering teams, a slight change is needed in the balance between work carried out internally and externally.

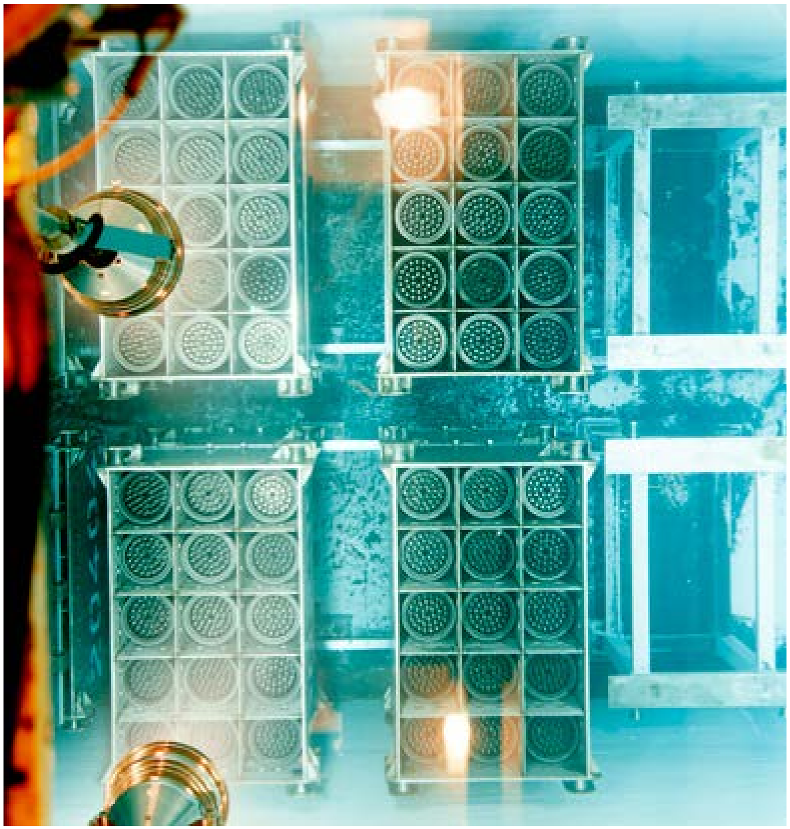
Overall, managers must be more involved in the assessment and development of their teams' skills.

FROM AGRS TO PWRS: A MAJOR TRANSITION THAT MUST BE HANDLED CAREFULLY

EDF Energy has decided to withdraw Hunterston B from operation no later than early 2022 and Hinkley Point B by mid-2022 after over 45 years of operation. The withdrawal dates for the other AGRs, up to 2030, will be progressively defined. This marks the start of a major, complex transition.

First and foremost, as with Fessenheim, nuclear safety must remain the overriding priority of every reactor right up to the last day of operation. Adequate consideration must be taken when adapting maintenance programmes, while continuing to motivate staff and maintain adequate resources. The independent view and vigilance of the Independent Nuclear Assurance (INA) will be essential during this transition period, and it should continue to have the necessary resources.

Considerable vigilance will then be necessary while the spent fuel is unloaded and removed. Defuelling an AGR places greater demands on fuel handling staff and facilities than a PWR.



AGR fuel pond

Despite the fact that the two reactors at Hinkley Point C will be entering into service, the workforce will be much reduced on the AGR sites being decommissioned and within the corporate support functions. Most of the remaining jobs will move from an AGR to a PWR technology. EDF Energy's workforce and skills will therefore undergo significant changes, which will need to be actively managed over the next ten years.

TEN-YEARLY OUTAGES: JUGGLING A WORKLOAD THAT HAS ALREADY REACHED MAXIMUM CAPACITY

Periodic safety reviews are carried out every ten years. In France, these lead to a high number of modifications during each ten-yearly outage (VD).

In order to meet particularly ambitious nuclear safety objectives, considerable work is being carried out during the current VD4 outages on the 900 MWe fleet to extend their service life beyond the initially envisaged period (*see Chapter 8*). This adds to the work already under way for the VD3 outages on the 1300 MWe fleet and the current VD2 outages on the N4 fleet. All this has significantly increased the engineering and implementation workload.

The VD4 900 modifications were initially grouped into two packages to even out the workload (studies and installation); an additional package was then defined following the 'experts' standing group[6] meeting in November 2020. The downside of this division into packages is a lasting lack of consistency between reactor configurations on the same site. This will require particular vigilance during operation.

The large number of additional modifications specified at the end of the reviews has resulted in a significant and unexpected engineering workload. This can only be dealt with by sub-contracting and postponing studies for the future VD4 1300 outages, thus sowing the seeds of future problems for these VD outages.

Operating experience from the first VD4 900 outages will make for better standardisation in the next reactors. However, implementation of this OPEX will be complex due to the number of simultaneous VD outages (4 in 2021, 5 in 2022 and 2023), which will place significant strain on the industry and engineering.

The modifications carried out during these VD outages are making significant improvements to the nuclear safety of the design. Although each modification makes sense when considered on its own, there seems to be an inadequate balance between their safety benefit versus the increased complexity of operation due to accumulative effects. I believe it is essential to work with the ASN and IRSN to manage the flow of modifications, taking account of the study and implementation workloads as well as human factors and the Operator's capacity to take ownership of them.

[6] *Groupe Permanent réacteurs: group of experts advising the ASN on the main nuclear safety issues*

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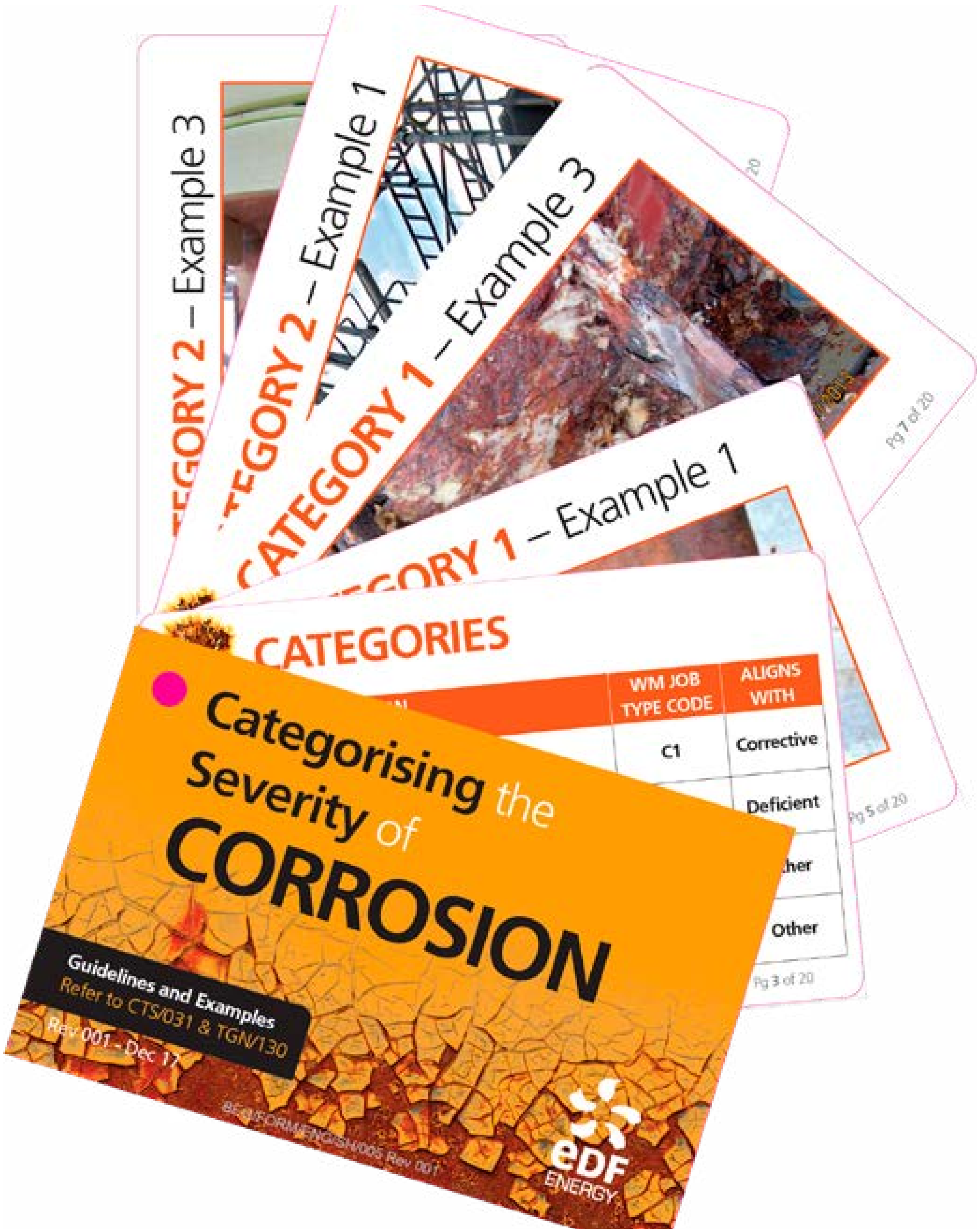


Corrosion cards at EDF Energy

Despite a year marred by the Covid-19 crisis, nuclear safety results have improved in 2020 in both fleets.

In France, the number of automatic reactor trips fell to a record low. In the UK, the defect backlog continues to fall.

The number of technical specification non-compliances remains high in both fleets.

Operational nuclear safety 01

All the indicators point to an improving picture overall in both fleets, it being understood that nuclear safety cannot be reduced to its indicators alone.

IN FRANCE, SATISFACTORY RESULTS

There was one significant nuclear safety event graded Level 2 on the INES scale in 2020. This was related to a generic problem on the generators. The number of Level 1 events was stable (1.4 per reactor). The total number of Level 0, 1 and 2 significant nuclear safety events (717) continues to reflect a good level of detection and transparency.

I commend the good results achieved at Fessenheim given the withdrawal of its two reactors from service.

GROUNDS FOR SATISFACTION

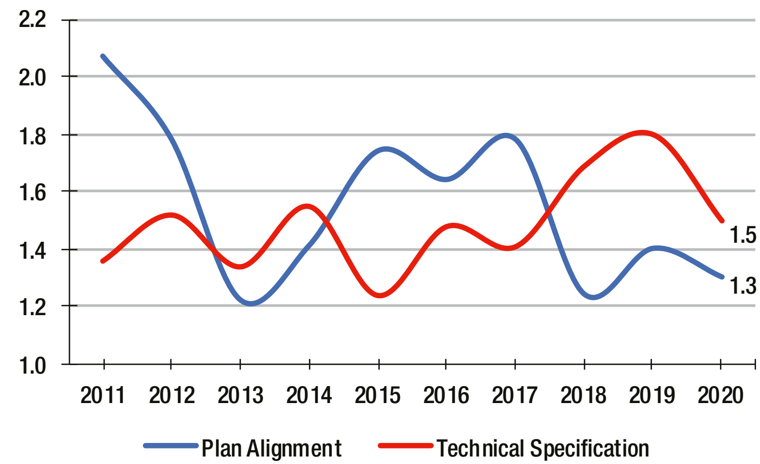
The DPN's efforts to reduce the number of reactor trips have borne fruit: there were 14 automatic trips in 2020. This equates to 0.29 trips per 7000 hours critical, which is the best ever performance. In addition, there were 2 manual trips in 2020

The safety system availability indicators remain excellent.

AREAS OF CONCERN

The number of technical specification non-compliances improved in 2020, but remains high at 1.5 per reactor (compared with 1.8 in 2019 and 1.7 in 2018). Large disparities were found between sites, highlighted by the fact that 53% of these non-compliances were accounted for by six sites alone. This confirms the need to consolidate the action plan launched in March 2020 to manage the sensitive situations identified as the causes of technical specification non-compliances, including: targeted actions, operations and maintenance training, and the publication of operating guidelines. This is all the more necessary now in view of the ever-increasing complexity of the standards (*see Chapter 8*).

The number of plant alignment errors remains high at 1.3 per reactor, and is comparable to the last two years (1.4 in 2019 and 1.2 in 2018). I hope that the actions undertaken to reduce the number of technical specification non-compliances will also help to reduce the number of alignment errors. The continuous use of human performance tools (HPT) is key to making progress in these matters.



Plant alignment errors and non-compliance with technical specifications, France

Total unavailability of an engineered safety feature

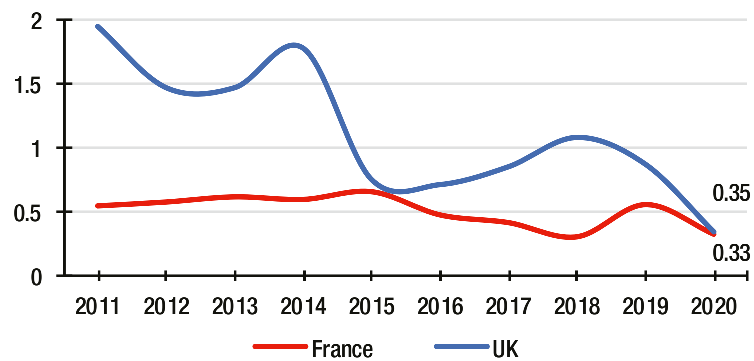
This incident involving the auxiliary feedwater system occurred at one plant when the train A turbo-pump was made unavailable to allow minor maintenance work to be carried out on the steam intake valve. However, train B was already unavailable due to planned maintenance. This led to the total unavailability of this engineered safety feature for almost 44 hours. It was eventually detected by the deputy shift manager.
This event revealed significant shortcomings in the plant isolation management procedures:

- The shift manager gave the go-ahead to remove the pump on train A before train B had been requalified.
- Train A was isolated without verifying the status of train B.
- No information was forthcoming from the control room when train A was isolated.
- The error was discovered very late in the event, both by the FIS and the operations teams.
- The maintenance teams did not realise that they were performing an intervention on 2 trains in parallel.

AN IMPROVING PICTURE IN THE UNITED KINGDOM

I note with satisfaction that this year there has not been an INES event greater than or equal to 2, and that there has only been one in the last ten years. The number of Level 1 events has never been so low, with just one such event in 2020 (0.07 per reactor) compared with 4 in 2019 (0.27 per reactor). However, as I have pointed out before, the British and French safety authorities apply different declaration criteria, hence we cannot make direct comparisons between the numbers of Level 1 events in each country. The number of Level 0 events per reactor remains stable and reflects a good level of transparency.

I mentioned in my 2019 report how little progress had been made with regard to technical specification non-compliances. The situation in 2020 has deteriorated further.



Number of unplanned automatic and manual trips, France and UK

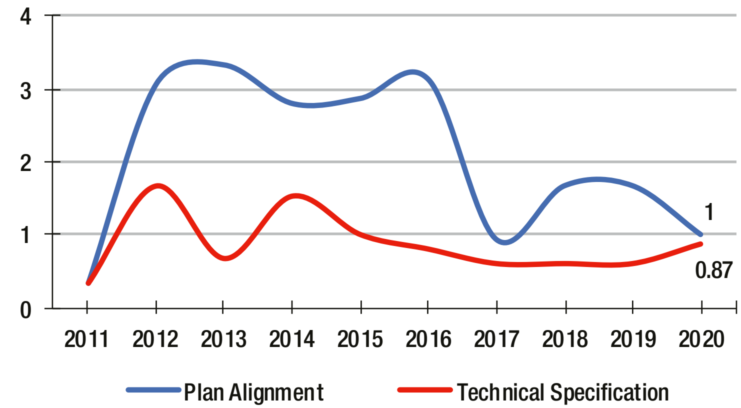
GROUNDS FOR SATISFACTION

The number of automatic and manual reactor trips continued on a positive downward trend, falling to 0.35 per 7000 hours of criticality (0.88 in 2019), the fleet's best ever result. Efforts to improve control room standards, equipment reliability and experience sharing have been extremely effective. However, one recent automatic reactor trip serves as a reminder that human error is always possible and that the use of human performance tools is a must.

The number of alignment errors has also seen a significant decrease, falling to 1.0 after standing at 1.67 for two consecutive years. Enhancements have been made to the Autolog tool[7] to display all system unavailability and provide additional information during post-maintenance handover tests.

[7] *Electronic tagging tool used by operating teams*

Safety system equipment reliability is good and continues to improve in the AGR fleet. Sizewell B PWR achieved 100% safety system availability for the thirteenth consecutive year.



Plant alignment errors and non-compliance with technical specifications, UK

AREAS OF CONCERN

The number of technical specification non-compliances has risen to 0.87 per reactor, having remained static at 0.6 events for the past three years. More work is needed to determine whether there are any common causes for these events and to define corresponding actions.

Anomaly relating to neutron flux measurements

When one of the AGRs was restarted, the reactor protection system did not behave as expected when the power was being ramped up. Start-up was interrupted by the automatic system and the reactor was tripped manually.
Investigations found that one of the three flux measurement systems was not operational due to a test device having been left in place after the regulatory tests were completed the week before.
Although this abnormal condition was evident on the instrumentation in the central control room (flux indications, lit indicators and protection system alarms), the significance of this information was only belatedly understood by the operations team. In accordance with procedures, they queried it with the duty reactor performance engineer, who unfortunately gave them the wrong advice. They continued with the restart with one flux measurement system partially unavailable.
This was classified as an INES Level 1 event.

Pressure equipment is subject to both Pressure Safety System Regulations (PSSR) and nuclear site licence conditions to ensure the safety of personnel and to guarantee nuclear safety respectively. The corresponding inspections needed to ensure compliance with both sets of requirements are very similar, although different time frames apply to each. EDF Energy has detected that PSSR deadlines have been missed for several reactors. These missed deadlines, which have been confirmed to have had no actual safety impact on the facilities, demonstrate a lack of knowledge with respect to PSSR that needs to be addressed.

SATISFACTORY FUEL PERFORMANCE

Fuel assembly cladding forms the first barrier between radioactive material and the environment, hence it must remain leaktight. Fuel assembly failure rates remained at a satisfactory level in both fleets.

In France, the failure rate was 0.11% as in 2019, which corresponds to a total of 7 fuel assembly leaks identified in 6 reactors. Most cladding failures are caused by foreign matter and debris resulting from stress corrosion of the friction springs. A new heat treatment is now being applied to these springs, which should improve their resistance to this phenomenon. Foreign matter from the grid plate was found on another type of fuel assembly in 2020. Investigations into this phenomenon, new to France, are ongoing.

Twelve fuel assemblies could not be reloaded (compared with 23 in 2019 and 4 in 2018) due to damage at their top end (S holes) discovered during handling.

Other than the temporary measures currently in place, MOX fuel anomalies (see my 2019 report) remain the focus of extensive work.

A corrosion deposit phenomenon (CRUD) was discovered in one reactor in 2019 (see my 2019 report). The affected fuel assemblies were cleaned and examined thoroughly. While waiting to be able to use them once again, a specific set of fresh fuel assemblies was fabricated with the appropriate enrichment levels. The safety case was drawn up for this specific refuelling operation.

In the UK for the first time in 20 years, not a single fuel failure was reported in the entire AGR fleet. The high number of fuel failures recorded in the past few years (5 in 2019 and 2018, and 8 in 2017) were caused primarily by carbon depositing on the fuel cladding and hence reducing the heat exchange efficiency. This issue has been alleviated by various modifications to the fuel design and operational parameters (see my 2019 report).

Sizewell B has now had no fuel cladding failures for over eleven years.

IMPROVED HOUSEKEEPING

Housekeeping in France remains satisfactory overall. However, there is too much corrosion in some areas, especially the pumping stations (See Chapter 3). The DPN's Nuclear Inspectorate has also reported some discrepancies in cleaning standards, noting in particular that oil spills are not being managed in line with procedures.

The defect backlog is decreasing at most sites, mainly thanks to the rapid maintenance teams (*équipes d'intervention rapide,* EIR) who handle the majority of urgent defects. This trend must continue. For those sites struggling to address this issue, I recommend that they boost the EIR teams, with the right staff with the right skills, and maintain its organisation during outages.

Prevention of automatic reactor trip - Blayais nuclear power plant

Housekeeping in the UK continues to improve. In particular, efforts have been maintained at sites nearing their end of life. Corrosion is still a problem here too and I note the improvement actions taken to address it. The fleet-wide strategy is delivering tangible results. However, there is still much to do and I will be monitoring progress.

Actions aimed at reducing the defect backlog have delivered the expected reduction in the number of defects. Technicians are rightly proud of their facilities and are keen to correct any errors. However, I regret to say that the weekly maintenance programmes are not robust enough; tasks are often delayed or cancelled at short notice before equipment can be replaced. The phased introduction of Fix it Now (FIN) teams should help resolve problems more promptly.

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Covid-19 safety measures

In France and the UK, the nuclear industry made sure nuclear safety remained its overriding priority during the Covid-19 pandemic. It safeguarded the health and safety of its staff, continued to produce electricity, and fulfilled its duty as a public service provider. The Group's key strengths are behind this success, i.e. the individual and collective commitment of its staff, its strong nuclear safety culture, and its emergency planning skills.

The pandemic will nonetheless have enduring effects that need attention, such as: team fatigue, limited interpersonal contact, statutory outage deferrals, training course postponements, and suspension of international cooperation agreements.

A year overshadowed by Covid-19 02

The number of positive Covid-19 cases within the Group has remained relatively limited, with transmission usually due to the person's local and family environment. Unfortunately, there were two Covid-related fatalities; a member of staff at Hinkley Point B and a sub-contractor of Framatome.

The handling of the Covid-19 crisis, the safety measures deployed, and the care provided for staff and contractors, were appreciated by all. Across the board, management and medical staff worked together efficiently. The remarkable dedication of staff, their sense of duty and professional conduct must be applauded; the fleets were able to face adversity.

LOCKDOWN: CLEARLY DEFINED PRIORITIES AND EFFICIENT ORGANISATION

The organisation in both fleets was immediately adapted to deal with the health crisis, relying on their emergency response resources and pre-existing pandemic management plans. Training in emergency preparedness also contributed to its good performance.

In France, the organisation of the plants was amended to protect the health of its workers and to ensure that shift teams, on-call staff and essential workers could all remain operational:

- Transition from 7 to 5 shift teams, including members from each team on reserve at home
- Pairs of on-call teams A and B (two weeks on call, two weeks in isolation at home)
- Enhanced serenity within the main control room, remote handovers, and regular disinfection
- Working from home was required for all those not considered strictly necessary onsite.

Similar measures were implemented in British plants in early February, well before the first case of Covid-19 was detected in the United Kingdom.

Working from home became standard practice for staff in the corporate services, engineering, and R&D.

When it was possible to continue manufacturing, specific measures for remote monitoring, delegation or inspection via video means were implemented, some of which were quite innovative.

Throughout this period, actions focused on completing only those tasks that were strictly necessary, which thus simplified work planning; this had a positive effect on peace of mind and quality of work. Logically, short-term requirements became prevalent. This explains why training programmes were suspended; I regret that training has only just regained the attention it deserves. On a more general level, a clearer idea of exactly what activities were postponed only came to light over time.

Owing to its activities in China, Framatome had to deploy its emergency organisation as early as the end of January. In France, Framatome coordinated its actions with EDF, which provided a great deal of support (help to apply the government directives, procurement of masks, etc.). The widespread introduction of working from home was well-accepted by its staff and led to the adoption of new methods (e.g. remote supplier inspection procedures). The safety measures enforced in factories made it possible to maintain production.

DISRUPTION TO UNIT OUTAGES

All of the contractors working for the DPN were initially sent home as a precautionary measure when the first lockdown was announced. The conditions for their return were then carefully examined taking into account the site, the operations involved, the safety measures required, the type of transport, accommodation possibilities and canteen options. The DPN's objective was two-fold: to protect the health of workers, and maintain its generation capacity for the following winter. Efforts converged on the top five most important outages, activities on the others were progressively expanded thereafter.

Both fleets were quick to publish their own Covid-19 guidelines such as: compulsory medical visit in the case of symptoms, social distancing (floors markings), frequent hand washing, ventilation of rooms, fewer passengers on onsite transport, specific rules in canteens and regular disinfection of surfaces. Well-received and assimilated, these guidelines have provided staff with a clear baseline for working onsite. In the UK, thermal imaging cameras were set up at site entrances to detect anyone with an elevated temperature.

Great care was taken to make sure sub-contractors did not feel disregarded; very close relations were maintained throughout the

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lockdown via frequent conference calls to foster cooperation and mutual support. I can attest to the quality of this work.

Areas with a high staff density were more complex to handle, such as site entrances, changing rooms, and entry/exits of radiation-controlled areas where radiation protection and health rules both apply. In France, mask-wearing proved contentious at the start of the pandemic and only resolved when their widespread use fell into line with the government's directives; this greatly simplified relations with contractors thereafter.

The DPN and EDF Energy also set aside extra time for the ongoing statutory outages, preferring to instil confidence in the work rather than trying to make up lost ground. The outages greatly benefited from this stance.

Reprogramming the statutory outages entails a great deal of work, whether in France or the UK; the entire outage programme will be impacted for several years. I note that requests to delay the application of regulatory deadlines remained an exception and that specific arrangements are in place to appraise delays or cancellations in planned maintenance activities. I believe it essential that the independent nuclear safety oversight teams be actively involved in this area.

Fuel procurement was successfully maintained thanks to remarkable efforts in scheduling, forward planning of onsite deliveries, strategic stockpiling, and stock management (raw materials, semi-finished products and fuel). The Nuclear fuel division (DCN) and EDF Energy kept in close contact with their suppliers and sub-contractors. Excellent coordination with the French public authorities also made it possible to organise all fuel transport operations.

EXTENSIVE DEPLOYMENT OF WORK-FROM-HOME

Working from home quickly became widespread. I would like to commend the efficiency of the IT departments that were able to absorb the sudden peak in demand for internet connection, laptops and remote access within a very short period of time.

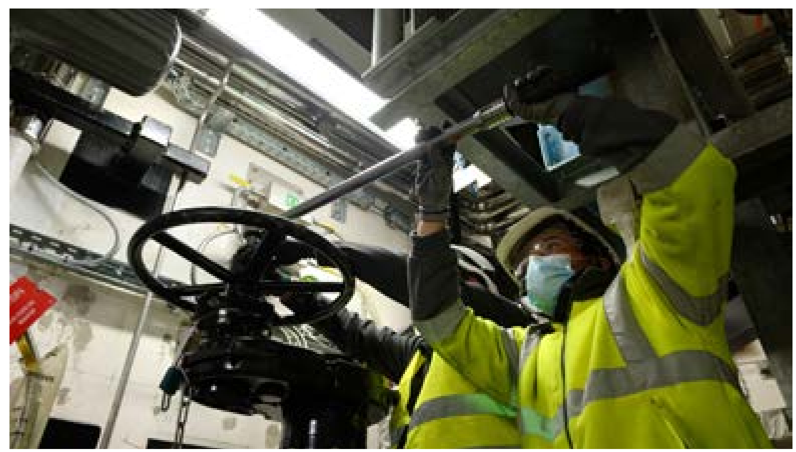
On a similarly positive note, electronic exchanges tended to be better formalised and more concise, while the completion of certain tasks benefited from the more peaceful conditions. I also noted that managers were focused on keeping in contact with their team. Staff tended to appreciate this close contact and the increased number of team meetings.

On a more cautious note, informal communication channels were lost, presence in the field was weakened, social ties were severed, cohesion was undermined, and the difficulties of weaker teams were amplified. Efforts especially focused on the mental well-being of isolated people. Although routine meetings between staff familiar with each other generally ran smoothly, it cannot be said that working from home is conducive to building interpersonal relationships, to developing skills by cross-fertilisation of ideas, to collective thinking processes, and to creativity. Not everyone experienced working from home equally; it often depended on their living conditions, such as whether they had children, etc. While working from home is destined to become part and parcel of our post-Covid lives, it would be unwise to consider it as a cure-all or as the main method of working in the future.

STAYING FOCUSED ON NUCLEAR SAFETY

ROBUST LEADERSHIP IN NUCLEAR SAFETY

The directors of the DPN and EDF Energy kept their focus steady on their overriding priority: nuclear safety. As the operational management of the pandemic was entrusted to emergency response leaders, the directors were able to maintain effective oversight from above.



Working during the Covid-19 pandemic

The DPN became aware of the risk of slipping towards "producing electricity despite Covid-19" rather than "producing electricity in complete safety". This risk was countered by reaffirming its overriding priority for nuclear safety. As a result, the fleet implemented very decisive communications, special CSNE[8] meetings, open group discussions with the plant directors, and a request to be challenged by the independent

[8] *DPN Nuclear safety review committee*

nuclear safety oversight (FIS). Identifying, sharing and processing issues, such as the risk of falsely believing in safe conditions when absent from the field, are all testimony to a strong nuclear safety culture.

Across the channel, EDF Energy Nuclear Generation and the Hinkley Point C project implemented a set of similar measures. Every day, the Chief Nuclear Officers (CNO) held meetings with site management to discuss strategic matters. Pandemic working groups were also set up at all sites to discuss operational issues, bringing together site staff and members of senior management teams.

All in all, there were no signs of significant deterioration in nuclear safety, nor incidents resulting specifically from the Covid-19 context.

INDEPENDENT NUCLEAR SAFETY OVERSIGHT ON HIGH ALERT

In the French plants, nuclear safety engineers continued their daily ‘cross-examination’ of safety (confrontation) with the shift managers, albeit remotely. Relations between the independent nuclear safety oversight and the plant director, which are nothing short of essential, may have waned in some plants. I understand that special care was taken to deal with the risks of anomalies, particularly with respect to the inspection actions actually completed.

The DPN’s Nuclear Inspectorate (IN) had to defer its site assessments. It has taken on an emerging independent nuclear safety oversight role at DPN senior management level, which I see as a very positive move. The Nuclear Inspectorate joined several operational-based meetings, drafted weekly reports on nuclear safety, and regularly took the pulse of independent nuclear safety oversight teams in the plants. A number of key points were raised, such as the need to rapidly resume training programmes.

In the UK, the Independent Nuclear Assurance (INA) remained onsite, increasing their frequency of field assessments, and taking part in numerous operational-based conference calls. It did not detect any significant slackening in nuclear safety attitudes. It continued to fulfil its independent nuclear safety oversight role at senior management level, including participation in all Covid-19 working group meetings. During such occasions, at strategic level, the INA voiced its opinion on modifications to the shift schedules and on maintenance schedule deferral arrangements.

MUTUAL TRUST AND CONFIDENCE WITH THE NUCLEAR REGULATORS

The Nuclear & conventional fleet directorate (DPNT) and the plants have maintained regular contact with the French regulator, the ASN, providing weekly updates on the situation. All onsite inspections were suspended during the lockdown, and documentation inspections were carried out remotely. I was told there was a proliferation of questions in some cases, which generated a certain amount of ambient stress.

Relations with the UK regulator, the ONR are strong. The ONR stopped its onsite presence but often took part in internal operational conference call meetings as an observer. It entrusted the INA with a number of tasks to complete on its behalf.

A PANDEMIC FAR FROM OVER

When the first lockdown was lifted in late spring, activities were not really resumed because they had not really stopped. Staff gradually came back to work onsite and training programmes restarted although some went online.

When the second lockdown was announced in late October, working from home once again became the golden rule for all those not required onsite, following the procedures that had already been tried and tested. Health and safety measures continued to be applied onsite; in fact, they were never suspended. This strategy proved to be efficient. During this period, most positive Covid-19 cases were again a result of catching the virus from a family member or social group rather than at work. For this reason, maintenance work and statutory outages could proceed with no significant changes. However, work during a statutory outage had to be reorganised at a UK site located in a region greatly impacted by Covid-19. On the whole, the second lockdown did not cause as much disruption as the first.

MY RECOMMENDATION

Based on the experience gained so far from this pandemic, I recommend that the directors of the DPNT, EDF Energy and the DIPNN pay attention to:

- **Simplification by keeping the good practices already observed in the field**
- **Training in the key professions by identifying those that must be maintained during a pandemic**
- **Working from home, as its deployment cannot be simply extrapolated into the new post-Covid normal.**

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Sizewell B nuclear power plant

The Group's overriding priority in all its activities is nuclear safety, and this fundamental value is clearly shared by all.

Yet the high degree of rigour and formalisation that are synonymous with nuclear safety have the potential to cause a gradual shift of focus from performance to process.

Preventing this from happening requires sustained focus on the plants, meaningful managerial presence in the field, competency development and greater accountability.

Revitalising a culture of accountability and performance 03

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NUCLEAR SAFETY CULTURE AND LEADERSHIP

UNWAVERING FOCUS ON NUCLEAR SAFETY

An embedded safety ethos, a wealth of expertise and unwavering sense of purpose are all evident in operations on both sides of the Channel.

Nuclear safety is a clear priority in plant operations. Key strengths include transparency, clear and direct communication, and opportunities for discussion and debate at all levels. Safety culture surveys and improvement initiatives are being implemented more widely. Managers are requesting to be challenged by the independent nuclear safety oversight organisation.

The Group's handling of the Covid-19 crisis was testament to its safety culture, as reflected in the messages and decisions embodied by the leadership teams in both fleets (*see Chapter 2*).

BUT WITH AN OVERLY PROCESS-CENTRIC CULTURE…

All too often results are measured in terms of how an action plan is progressing or how well processes are applied. The prevailing belief seems to be that if a process is well written and is followed correctly, the desired result will be achieved. Yet we need to look beyond this somewhat mechanistic view. Although processes are necessary, the quality of the final results is what matters most; we need to assess results based more on actual performance, with a clear focus on the plants and those who operate them.

This process-centric approach has been fuelled by a tendency to multiply the number of action plans and add new specifications in the aftermath of an event, rather than going back to basics. It is reinforced by the use of a somewhat esoteric language ('protected interests'), which distances staff from reality.

… AND, IN FRANCE, TOO OFTEN BEING LED BY THE ASN

The propensity to deal with technical safety issues primarily through the French nuclear regulator's (ASN) questions and authorisation procedures persists in the fleet, in engineering and even in R&D (see my 2019 report).

Like it or not, and contrary to the principle that the Operator has primary responsibility, it would appear that the technical aspects of nuclear safety are too often being driven in reality by the ASN and the Institute for radiation protection & nuclear safety (IRSN). This is a matter of concern. From the Group's perspective, waiting to be pushed into action by the ASN to address a problem is inappropriate.

Yet we should bear in mind that the ASN's demands take up the lion's share of engineering and corporate service resources. Regulating the number of questions, requests and new requirements would be possible by encouraging deeper technical discussions earlier on in the process.

A NEED FOR SIMPLIFICATION…

As I mentioned in my 2019 report, I believe that increasing complexity is one of the greatest concerns for nuclear safety. Whilst this risk is widely recognised, I observed too few examples of simplification on a large scale. In France, for instance:

- The plants do not seem to have addressed the issue of maintenance documentation quality, with the tendency being to produce excessively detailed documents that are difficult to read.
- Annual safety reports[9] are rarely shorter than 60 pages and tend to focus on processes and action plans; there needs to be a clearer picture of nuclear safety and the main challenges facing the plants.
- The volume of work associated with the ten-yearly outages continues to rise and is reaching a critical level (*see Chapter 8*).
- There is still a high degree of complexity in operations and engineering standards. The DPN's current efforts to distinguish between regulatory and managerial requirements are insufficient to address the issue.
- Not only are the organisations of engineering and new-build projects structured differently, but they are also still too complex (*see Chapter 9*).

Simplification will inevitably lead to a greater sense of accountability, though this is still stifled by the burden of reporting back up the chain.

[9] *These reports are written by all DPN plants and corporate departments.*

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Management will have to accept lightening the reporting load; for instance, I find the importance attached to managerial field reports at the DPN quite staggering.

… AND GREATER ACCOUNTABILITY

Restoring a greater sense of individual and collective accountability is a must in my view. The key is to never lose sight of the inherent risks of nuclear power, keeping these risks under control, and being held accountable for one's actions.

Accountability

The French word responsabilité can mean two things in English: 'responsibility' and 'accountability'. Responsibility refers to a person's sphere of duty or obligation defined by the nature of their job description, employment contract or role within the company. Accountability refers to the way in which individuals fulfil their responsibility. It is the act of being answerable - or liable to be called to account - for one's actions. Unlike responsibility, accountability cannot be delegated.
Although accountability is widely accepted as a typically English word, its French (and Latin) origins are nevertheless apparent: *se sentir comptable* (to feel accountable).

This culture of accountability and performance is inextricably linked to a strong managerial presence in the field, which should extend to all core activities. Timely decision-making at the right level of the organisation is important, without pushing decisions back up the chain unnecessarily. I am pleased to see that leadership teams in France and the UK alike are conveying a similar message. I appreciate that the DPN Start 2025 project also encompasses this goal.

EARLIER DETECTION AND SUPPORT FOR PLANTS IN DIFFICULTY

All plants have their highs and lows. Higher performing plants can experience downturns, whilst others deemed to be struggling can always raise the bar and reclaim their place among the best.

There can be various early warning signs of declining performance, including overconfidence due to a prolonged period of success; isolation; rapid turnover in teams and departure of key staff; lack of managerial presence in the field; lack of cohesion; loss of operations leadership; and an accumulation of technical issues.

The conditions for recovery are also widely known and include collective awareness, a clear diagnosis and action plan that are shared by all, cohesion and leadership from management teams, reduction of silos, and development of skills and attitudes.

Yet both fleets seem to have missed the warning signs on several occasions; it has taken the regulators (ASN, ONR), WANO, or a dramatic deterioration in performance to crystallise awareness in some cases. Several plants have subsequently received a high degree of corporate-level support, which should reap rewards in the long term.

I will be very interested in the strategies devised to help detect early warning signs and to support plants in an appropriate and timely manner; the speed of response will be a determining factor in any recovery.

MANAGING THE TRANSITION IN THE UK

The UK's AGR fleet is gradually being withdrawn from service (*see My view*): the oldest reactors have now been operating for over 40 years and the maximum lifespan of graphite - recognised as the limiting factor for this technology - is fast approaching. I applaud the clarity and level of responsibility with which EDF Energy has defined the schedule for closing the first of these facilities. The time lines for the remaining AGRs will be decided based on how the graphite has aged and on the specific features of each reactor core. These safety cases – drawn up on a case-by-case basis – will also require a high-level of technical expertise.

An AGR pile cap

The in-core boilers are another limiting factor impacting the AGR lifetime. It is important to continue developing appropriate tools and methods for conducting boiler inspections. I also note that some - mostly electrical - components have now become obsolete. The fire risk associated with unreliable electrical equipment (*see Chapter 6*) must be managed.

This is a new period of transition for the AGR fleet which includes: continued operation of some reactors for a few more cycles; preparation for defuelling and dismantling; planning for the future of each facility; reduction and transformation of corporate services; and a gradual transfer of investments to decommissioning. Complex AGR fuel route activities will be in high demand for three years after shutdown.

Safety must remain paramount throughout, up to the last day of operation and continuing into the defuelling stage. Maintaining staff commitment, sense of pride and skills will be vital.

Sizewell B, currently the UK's only PWR, has now reached its 25-year anniversary and will soon be making preparations to extend its 40-year lifespan. This phase will involve yet more maintenance, equipment replacement and modifications. The site's capacity to conduct all of this work will need to be monitored closely. A high level of support is required from corporate services, and closer cooperation with other PWR fleets would be desirable.

OWNERSHIP OF ACTIVITIES AT THE HEART OF NUCLEAR SAFETY MANAGEMENT

OPERATIONS

I have often observed good leadership by the Operations departments; this is critical to effective nuclear safety management. The daily balancing a plant's safety priorities falls to the shift manager. Any weaknesses in operational leadership are usually a sign of a plant in difficulty.

In France, monitoring and robust control room rigour must remain a key focus area for plant management teams, as flagged up by WANO: a third operator is now present in the control room at all plants to help strengthen this area of weakness. However, their role in the 'core operations team' standard does not seem to have been interpreted uniformly across the fleet. I will be keeping an eye on how this position evolves.

Aside from the mandatory annual 10-day simulator training, the type and amount of training and instruction vary considerably from one plant to another. I have seen many good practices, such as simulator refresher courses prior to transients, independent digital simulator training and group sessions requested by shift managers. However, these initiatives are inconsistent across the fleet and I think more efforts should be devoted to skill development.

I also believe that operating experience should be leveraged to a far greater extent. I am disappointed that after the INES Level 2 event that occurred at a French plant in 2019, appropriate lessons have not been learned within the usual time frame by the plants, the Operations & engineering training department (UFPI), or even by senior management. It is welcome news that the DPN has stepped in to deal with the matter.

An operator in the control room - Flamanville 3

Remembering past accidents

This showroom is a joint initiative between EDF, EDF Energy and CGN. It is a travelling exhibition that addresses the main historical accidents - Three Mile Island, Chernobyl and Fukushima. This immersive experience offers a means of sharing and extending the lessons learned from these events through group or individual visits. Staff are encouraged to reflect on their understanding of nuclear safety and how it is put into practice today. The Three Mile Island accident, which occurred on 28 March 1979, is a prime example of just how easily an everyday operating scenario can rapidly deteriorate. It all started with the failure of the main feedwater supply to the steam generators. A series of technical failures, misrepresentations of the situation, inadequate procedures and inappropriate actions ensued, leading to core meltdown. One of the legacies of this accident is the fundamental change in how human factors are now incorporated into nuclear safety.

Similarly, an event occurred at EDF Energy Nuclear Generation in an AGR in 2020 (*see Chapter 1*). It would be well worth incorporating such events into the training provision to ensure lessons are learned and incidents are remembered to foster a more dynamic understanding of nuclear safety. A summary of the most significant events should be

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compiled and distributed to provide regular discussion opportunities. The 'showroom' set up by the three fleets (EDF SA, EDF Energy and CGN) is an excellent initiative.

UNIT OUTAGES AND MAINTENANCE

Managing the quality of maintenance and the reliability of reactor equipment is another inherent aspect of nuclear safety management. The way in which individuals are coached and mentored, how conditions are created for their success, and how technical skills are prioritised, are particularly important in this respect. Yet maintenance teams are hampered by many obstacles, like last-minute postponements, delays and overly detailed documentation, which disrupt workflows and have a negative impact on quality and motivation.

Scheduling must be realistic, robust and unifying so teams want to share the same goal; this is why it is an essential tool for delivering successful, high-quality maintenance. When non-compliances are detected, I am pleased to see that repairs are now the preferred solution wherever possible as opposed to lengthy substantiation reports. Full ownership of the plant undoubtedly requires greater knowledge of the design by the sites, particularly by the plant's engineering teams. This tends to fall within the remit of central engineering functions.

Maintenance activity - Gravelines nuclear power plant

It makes great sense for unit outages to be made the focus of the DPN's 2021-2025 project in light of the considerable number of issues with industrial practices and standards. For the same reasons, outage management is also a key objective in the UK.

DESIGN AND CONSTRUCTION

The *plan excell* (*see My view*) is a wide-reaching initiative launched in the wake of Jean-Martin Folz's recent audit of the French nuclear industry to address the issues that plagued new-build projects. Several of the plan's initiatives will also filter through into the fleet's engineering and construction projects.

Some of the technical non-compliances detected at Flamanville 3 (e.g. welds on the main steam lines or performance of heat exchangers on the component cooling and emergency service water systems) require extensive OPEX, given that their root causes are linked to the management of nuclear safety. Even though difficulties were anticipated and reported, no further action was taken to modify the studies or fabrications.

Although there have been many successful modifications across the fleet, some have had design flaws. The reasons for such non-compliances need to be examined as some seem to be due to a lack of proximity between engineering and the plants, or between EDF and sub-contractors, because of long and complicated supply chains.

INDEPENDENT NUCLEAR SAFETY OVERSIGHT

Independent nuclear safety oversight is generally well staffed at plant level and safety engineer expertise is of a good standard. Efforts should be made to raise the profile of this role and widen the talent pool. Safety engineers challenge shift managers, and they perform the daily 'cross-examination' of nuclear safety ("*confrontation*") with rigour. Any disagreements between the shift manager and the safety engineer go through an 'arbitration' process. This process should focus, in my view, on operational aspects rather than regulatory notification and categorisations. Significant event reports would benefit from better clarification of the root causes and the areas for improvement.

Positive developments at the Nuclear Inspectorate include: self-mandating on topical issues, increased involvement in the DPN's operational meetings, assuming an independent nuclear safety oversight role at senior management level (initiated during lockdown, *see Chapter 2*) and greater presence in the field to assess housekeeping during site assessments. However, its assessment methods tend to focus on process compliance and would benefit from being more performance oriented.

I am disappointed to see that fewer and fewer of the Inspectorate's recommendations are being taken into account; a more ambitious target needs to be set for the fleet's uptake of these recommendations.

The *Organe d'Inspection de l'Utilisateur* (OIU[10]) is manifesting greater confidence and authority. This role of inspector is challenging and requires management to provide the necessary support and protection from undue pressure.

The internal authorisation system - a form of delegation of ASN authority - is now firmly established. It is a robust, well-resourced and well-managed operation. This kind of virtuous circle increases Operator accountability.

WANO issued some positive recommendations about the independent nuclear safety oversight organisation in its follow-up corporate peer review of EDF SA: the good work needs to be continued.

Having laid the groundwork for independent nuclear safety oversight at the DIPNN in 2019, the pace of implementation slowed somewhat because of the lockdown. Analysis of the problems at Flamanville 3 certainly confirms the need for independent nuclear safety oversight in engineering: a strong independent oversight function in place at the time would have undoubtedly limited the impact and number of non-compliances.

The INA[11] is a robust effective oversight function; it is unafraid to ask questions, voice strong opinions, and is well respected by the ONR. It has a well-established and recognised on-site role, although there is some disparity in team profiles. In view of the planned job cuts in EDF Energy Nuclear Generation's corporate services, the INA will need to maintain adequate resources during this challenging transitional period.

MY RECOMMENDATIONS

To revitalise the Operator's sense of overriding responsibility for nuclear safety, I recommend that the directors of the DPNT, DIPNN, EDF Energy and EDF R&D strive to bring about a change in mindset, where it is more important to truly question "what we think is necessary?", before second-guessing "what the regulator might request?".

Building an active understanding of nuclear safety hinges on learning from past events that should remain at the forefront of everyone's mind. I recommend to the directors of the DPN and EDF Energy Nuclear Generation that a summary of the most significant events be compiled, updated and discussed regularly.

The INA will play a pivotal role in the UK's transitional period. I recommend that the Director of EDF Energy keep a close eye on its resources and positioning to continue fulfilling its role properly.

[10] *Internal inspection organisation*
[11] *UK's Independent Nuclear Assurance*

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Handling an AGR spent fuel flask

The industrial safety results are improving in France and have remained good in the UK.

Radiation exposure levels have improved in both fleets, but some events reveal inappropriate behaviours and a rather weak radiation protection culture.

Already commonplace in the UK, drug testing is gradually being rolled out in the French plants.

Industrial safety and radiation protection: refocusing on the fundamentals

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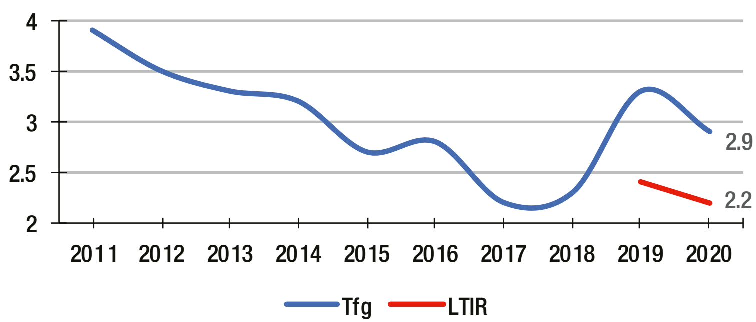
ONGOING EFFORTS TO PREVENT CRITICAL RISKS

A 'STOP' safety break was organised across the Group for the second year running. This initiative, which includes the participation of contract partners, allows for open discussions on ways of improving individual and collective industrial safety levels.

In France, the use of safety messages is still often rather formal and remote, lacking collaborative interaction. Widespread in the UK, it has raised awareness of critical risks and allowed for unrestrained discussions in teams.

IN FRANCE: A SLIGHT UPTURN IN RESULTS

At the Nuclear generation division (DPN), the lost-time injury rate (LTIR) was 2.2 (2.4 in 2019) and the overall accident rate (Tfg) of 2.9 improved compared with 2019 (3.3), without reaching the good results of 2017.



Overall accident rate (Tfg) and the lost-time injury rate (LTIR) at the DPN

The total number of accidents due to critical risks (work at height, load handling, electrical work) has dropped: 5 accidents with lost time (5 in 2019, 4 in 2018) and 7 accidents without lost time (11 in 2019, 6 in 2018).

In the engineering functions, the DIPNN results (excluding Flamanville 3) improved, with an LTIR of 1.0 (2.0 in 2019) and an overall accident rate of 1.7 (3.0 in 2019). At the DIPDE, the results also improved, with an LTIR of 1.5 compared with 1.8 in 2019.

At Flamanville 3, the lost-time injury rate has remained very high with an LTIR of 8.3 (5.9 in 2019) and an overall accident rate of 8.9 (6.5 in 2019).

On decommissioning sites, the LTIR was 1.1 (0.5 in 2019).

The number of slips, trips and falls within the DPN decreased, however the number of manual handling accidents has increased. In terms of critical risks, though there were fewer serious events, I am told that staff will walk under travelling loads, that work at height will be performed without being secured, that maintenance on electrical equipment will sometimes be carried out without making sure it has been de-energised, and that the correct personal protective equipment will not always be worn.

It is vital that progress be made in this area. This means strong managerial involvement in the field and a greater awareness of the risks at hand based on an individual approach to accountability. Contractors must be on the same page when it comes to committing to these improvements. Joint awareness-raising actions, training, feedback initiatives and managerial supervision must be intensified for this to be possible.

IN THE UNITED KINGDOM, THE RESULTS ARE STILL GOOD

The LTIR results are good at EDF Energy and have remained stable, reaching 0.3 in 2020 (0.3 in 2019 and 0.5 in 2018). This year, the industrial safety indicators reached their best or almost-best levels ever seen. The following measures helped achieve this:

- 'Zero harm' initiative launched several years ago, which is still ongoing
- 'I Always' campaign recently initiated with support from contract partners
- New training in industrial safety leadership, which had been lacking for years.

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However, I note that the number of accidents with and without lost time actually increased during the first lockdown, before dropping thereafter. EDF Energy and contractor staff may have had trouble focusing during this unprecedented time.

The results for Hinkley Point C are outstanding, with an LTIR of 0.89 (0.92 in 2019 and 1.18 in 2018), reflecting strong leadership in industrial safety. The main concerns remain work at height and load handling. I commend the development of the HPC Way project on industrial safety leadership; it brings suppliers together to share and improve on best practices. A silo containing aggregate collapsed on the construction site, though fortunately no one was injured.

Manager commitment is clearly visible both in the fleet and at Hinkley Point C, and this is true whether at corporate level or in the plants.

Collapse of a silo

A silo containing about 5000 tonnes of blast furnace slag used to make concrete suffered structural damage, causing the bottom to fall out and releasing a large dust cloud. The onsite emergency plan was triggered though nobody was injured and the emergency services were not required. The batching plant was designed and built by a second-tier sub-contractor; following the failure, it has been closed and an exclusion area has been created. The silo was seriously damaged and could not be repaired. The remaining smaller batching plants on the construction site were checked and no problems were detected.
Preliminary analysis of the faulty silo has identified a problem with the resistance of its bolted structures. The investigation is still ongoing.

PREVENTING DRUG AND ALCOHOL ABUSE

The specificities of the nuclear industry call for zero tolerance with respect to drug and alcohol abuse.

In France, testing has been set up in plants where the internal rules have been modified accordingly. Unfortunately, the Covid-19 pandemic has slowed down the modification process of these internal rules at plants that had yet to implement testing. This process needs to be resumed as quickly as possible.

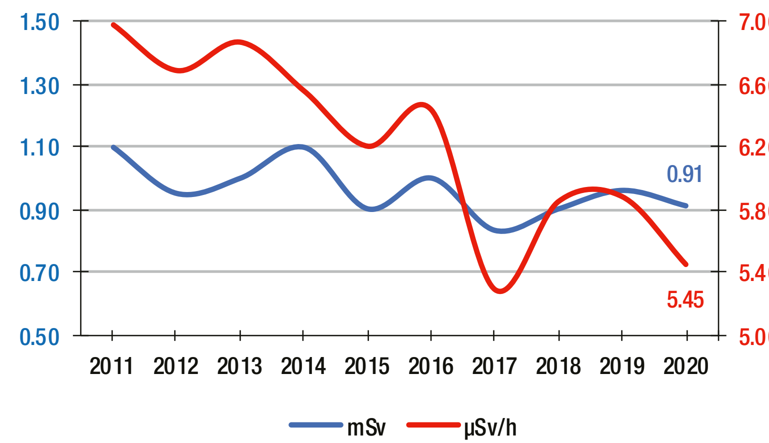
In the UK, about 6000 random drug and alcohol tests were carried out in 2020. Though the number of positive test results has risen slightly, it remains considerably lower than when compared with the national picture. A week-long awareness campaign on addictions was organised to encourage dialogue and staff commitment to prevention.

AREAS OF CONCERN IN RADIATION PROTECTION

In 2020, the Covid-19 pandemic completely disrupted the maintenance outage schedules and the volume of activities (*see Chapter 2*). Comparison with previous years is therefore complicated.

IN FRANCE: UNEVEN RESULTS AND EARLY WARNING SIGNS

In 2020, the collective dose of 0.61 man.Sievert/reactor is consistent with the DPN's objectives according to the number of operations planned for the year.



Mean individual dose and hourly dose (EDF and contractors)

The average individual dose for workers (EDF and contractors) reached 0.91 milliSievert (mSv) in 2020, which is stable compared with past years (0.96 mSv in 2019). A total of 73 operatives received an annual dose exceeding 10 mSv, compared with 151 in 2019. No operative exceeded 14 mSv. The regulatory limit is 20 mSv.

The hourly dose per worker (EDF and contractors) has resumed its positive downward trend achieving the second best ever results. The CADOR software is a good support tool that helps define and optimise the biological shielding that needs to be set up before starting an operation. However, I note that only 43% of the CADOR deployment programme was achieved.

Yet, there have been numerous cases (8) of external contamination wherein 25% of the annual regulatory limit was exceeded each time.

There has also been a series of radiation protection related events:
- Entries into radiation-controlled areas without a dosimeter
- Grinding operation on a pipe connected to the primary system, without any protective breathing apparatus
- Radiography-related incidents
- Failure to respect the rule prohibiting one person from carrying both keys required to access a red radiation-controlled area.

These warning signs call for greater commitment from everyone so radiation protection can regain its rightful place, as it is an integral part of the nuclear industry. I will monitor the progress of the radiation protection recovery plan launched by the DPN in December 2020.

Working on electrical equipment - Gravelines nuclear power plant

IN THE UK, SATISFACTORY RESULTS BUT SOME ISSUES REQUIRE ATTENTION

Because of their design, the collective doses in AGRs are inherently lower than in PWRs. In 2020, the collective AGR dose dropped to 0.013 man.Sievert per reactor (0.032 in 2019). This year, without a refuelling outage, the collective dose for the Sizewell B PWR was low at 0.031 man.Sv (0.26 in 2019), which is the best historical result.

The maximum individual dose for the fleet was 2.6 mSv compared with 4.37 mSv in 2019.

There were no reportable events with respect to radiography work.

As in industrial safety, some inappropriate radiation protection behaviour was observed during the first lockdown. For instance, the radiation protection team was not called as required when contamination was detected at the exit of a radiation-controlled area. Perhaps individuals were weary of having the subsequent manual where respecting the social distancing rules would not be possible. It must be made sure that such behaviours are not repeated.

Fuel route operations and maintenance in an AGR can generate rather high doses. The fuel route systems are complex and not entirely reliable; they will be in high demand for the two or three years it will take to remove the fuel following final shutdown of these reactors. Both the fuel route operators and the radiation protection staff will therefore have to hone their perception of the risks, which will be possible with adapted training.

MY RECOMMENDATIONS

Inappropriate behaviour in risk prevention was observed. I recommend that the directors of the DPNT, the DIPNN and EDF Energy strengthen the individual accountability of staff and contractors to better manage the critical risks in industrial safety and the fundamental rules of radiation protection.

In the UK, numerous fuel handling operations will be necessary as the AGRs come to the end of their service life. I recommend that the director of EDF Energy Nuclear Generation assure that the fuel route teams are well-informed of the radiation protection rules and that they are given proper support from specialists in the field.

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Control room simulator - Gravelines nuclear power plant

Nuclear safety relies on both the commitment and professionalism of the staff at EDF and its contract partners. Highly structured training plays a major part in skill development programmes.

In both fleets, nuclear safety events, quality issues and maintenance outage overruns are associated with inadequate skills.

Skills in engineering and project management do not always allow us to reach the required level of quality.

Making skill development a key priority for managers 05

People's skills develop throughout their careers and training plays a large part in this. Structured career paths, support in the field, practising technical activities, the support of experts and the involvement of managers are also essential for enhancing individual and collective know-how. The development of skills is one of the cornerstones of the *plan excell* (*see My view*) and a priority for the nuclear divisions.

RECRUITMENT AND CAREER PATHS

CONTINUING RECRUITMENT OUTSIDE THE COMPANY

A few years ago, EDF SA successfully renewed a significant proportion of its workforce. Tomorrow's professionals and skills depend on the appeal of both the technical jobs available and the attractiveness of the nuclear sector. Contract partners also tell me that they have difficulty in recruiting and retaining staff. Improving the appeal of jobs requires an industry-wide effort, including communication and the introduction of new programmes.

Following the recruitment surge in the 2010s, DPN staff numbers have stabilised, with 450 employees recruited from outside the company in 2020. The DIPNN's workforce is growing to deal with the increased workload (*see Chapter 9*). I believe a significant level of recruitment should be maintained: several roles are often needed to build the skills of tomorrow. In fields for which the in-house pool of candidates is small, the Group must be confident in recruiting externally, for example specialists in geosciences, fire or project management.

The recruitment of suitable candidates on completion of their apprenticeships must continue. This practice is already well under way in both the UK and France.

Co-recruitment[12] is also an effective way of developing skills. I am pleased that this is being used more widely across the company, not just in engineering and R&D, but also in other functions such as the DPN and the ULM[13].

BUILDING ATTRACTIVE CAREER PATHS

The lack of appeal of some regions, such as the Paris area, is often mentioned as being an obstacle to mobility. Some departments are proposing new ways of working to deal with this problem. For example, the Operations engineering unit (UNIE) has proposed working 2 to 3 days a week in Paris and the rest of the time elsewhere.

In France, aspirations towards various higher-qualified jobs in the maintenance and operations departments has resulted in some depletion of staff within the site workshops. This pool of essential practical skills should be rebuilt without delay.

Staff restrictions are resulting in people staying longer in their jobs. This is positive for professions in which it takes a long time to become suitably qualified and experienced, such as in engineering or project management jobs. I am pleased with the DPN's wish to promote long-term jobs in these professions. In parallel, I believe it is necessary to ensure there is sufficient inter-site and inter-departmental mobility, which provides unique opportunities that are beneficial both to individuals and to the company.

The organisation of career paths is one of the main ways of building skills. It is essential to build and manage skills across the Group. I have observed interesting examples in some fields: mobility between the DIPDE and the sites; between the DIPNN's technical division, the Core design and engineering group (GECC) within the Operations engineering unit (UNIE), the nuclear power plants and the DCN for fuel; and between the ULM and the nuclear power plants for maintenance. I encourage the widespread implementation of these approaches.

I am disappointed again this year to learn that there is still little movement from EDF Energy to EDF SA and between EDF SA and Framatome.

Internal retraining programmes, for example from the commercial division or Enedis, require considerable investment from the people and departments concerned. Their success is highly dependent on the relevance of the profiles selected.

In the UK, the transition from AGRs to EPRs will lead to radical changes in EDF Energy's teams over the coming years. In addition to the considerable changes in the numbers and locations of jobs, major adjustments also have to be managed. Essential know-how on the operation and dismantling of AGRs must be maintained and EPR skills must be developed (*see My view*).

[12] *Practice whereby a person recruited by one department takes up a first position in another EDF function in order to gain initial experience before joining their own department.*
[13] *Maintenance & Logistics Unit, which reports to the Conventional fleet multi-disciplinary expertise & industrial support division (DTEAM).*

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TRAINING AND SUPPORT

The Covid-19 crisis led to many training courses being postponed or cancelled in 2020 (*see Chapter 2*). Arrangements must be defined as to how these delays can be recovered.

MORE EFFICIENT USE MUST BE MADE OF TRAINING RESOURCES

In France, training is organised centrally: the UFPI[14] is responsible for organising training courses in response to requirements expressed by the DPN, the DTEAM, the DIPDE or the DIPNN. As these requirements are often in the same fields, these functions could benefit from coordinating themselves better.

In the UK, the approach is less centralised. Programmes are developed for the whole fleet, and heads of department are responsible for ensuring that they are delivered on their own sites. The delivery of the programmes by the sites is also assessed by an external body, the Training Standards Accreditation Board, which I consider to be a good practice.

Training Standards Accreditation Board (TSAB)

In the UK, the training accreditation process assesses the effectiveness of programmes concerning nuclear safety and ensures that they enable EDF Energy and their partners to be approved as Suitably Qualified and Experienced Personnel (SQEP).
Before a site is accredited for a programme, it assesses consistency with the training framework defined at corporate level and explains how it meets the objectives. A team of experts from the fleet then visits to observe the courses and question employees.
The TSAB, which is made up of independent experts, then meets two or three months later. It questions the site management on the effectiveness of the programme and the commitment of the heads of department to training their staff. Accreditation is granted for four years.

In France and the UK, the Group has excellent training resources: joint training departments, craft training centres and mock-up facilities on sites, the Bugey and Saclay campuses which have identical equipment to that used on-site, the Barnwood and Hinkley Point C training centres, etc. The resources are appropriate in terms of numbers and profiles, with an overall satisfactory balance between young and experienced trainers.

In France, the craft training centres and mock-up facilities at the sites are generally underutilised. In the UK, it is often the opposite: there are not enough craft training centres and they are overstretched. These facilities are a great help for training in technical practices and better use must be made of them.

Mock-up facility - Cruas nuclear power plant

In 2020, IGSNR observed several sessions led by trainers from the UFPI. I am impressed by their teaching skills and approaches, which combine theory and practice in well-equipped facilities. However, the time it takes to incorporate OPEX into training courses is regrettable (*see Chapter 3*).

E-learning is developing faster in France than in the UK. It offers a number of advantages: autonomy and accountability, easy access to a variety of learning material, flexibility and no need to travel. However, in some cases they are less suitable than conventional training courses: there are no discussions between attendees and no direct contact with the trainer, who can tailor what he says to topics that arise. I have also been told about difficulties many trainees have had in finding time for completing the e-learning, and also occasionally in meeting all the prerequisites. Managers must ensure there is satisfactory preparation and participation. I recommend that analyses be carried out to determine the most effective forms of e-learning (the most appropriate subjects, content, etc) before defining the part they play in training and in qualification processes. I suggest that EDF SA and EDF Energy work together on this.

[14] *Operations & engineering training department, which reports to the DTEAM*

GREATER INTEGRATION OF CONTRACT PARTNERS

Some contract partners on sites or in engineering functions have developed their own academies or training centres. It is an effective way of developing the skills of their staff.

In France, the GIFEN[15] and regional associations of contract partners are very committed to skill development and training.

Although contract partner requirements are similar to those of EDF SA, their training courses have become different over time. What is more, EDF sessions are not always full. I therefore urge that the initiatives of the PIRP[16], PCC-EO[17] and UFPI teams to make the programmes more similar be continued and that joint courses are organised, as EDF Energy has already done.

I also believe it is essential that contract partners spend more time training in the EDF mock-up facilities (see above).

In addition, I have been given a presentation on the Group's 'welding plan' (*plan soudage*). It includes a section on the development of individual, collective and industrial welding skills for the whole nuclear industry, and I will be monitoring its progress.

I visited Framatome's training centre: I believe it was a good idea to integrate it into the St-Marcel fabrication plant.

The welding plan

This is part of the *plan excell*. It covers the whole welding process to improve its management at all stages: design, execution and oversight.
On the EPR 2, the objectives are to halve the number of welds carried out on-site and to use more welding robots.
For the existing fleet, a management guide on how EDF monitors the non-destructive testing carried out by its contract partners will be drawn up in 2021 for detecting and dealing with defects as early as possible.
In addition to existing qualifications, an accreditation system for welders working on nuclear projects, graded according to the sensitivity of the welds, will be included in contracts from 2021.
All the welders on the Hinkley Point C construction site (more than 700 people over four years) will receive training leading to accreditation at the nearby Bridgwater training centre, which opened in September 2020. Another centre will be set up in Cherbourg in collaboration with other industry players, and will train around a hundred people a year from 2022 onwards.

[15] *French nuclear industry association*
[16] *DPN industrial policy and contract partner relations team*
[17] *DPN skill advisory centre for organisational effectiveness*

SPECIALISTS AND EXPERTS

During my meetings, I noted that experts appreciate how their position has evolved within the organisation and that the appeal of expert-level jobs is increasing.

Mentoring during on-job training at EDF Energy

As well as being proficient in their technical fields and contributing to the Group's strategies, experts play a key role in the development of individual and collective skills. They are also involved in identifying training needs. It is important to ensure that they are sufficiently close to the technical teams and that their day-to-day tasks leave them enough time to do this.

I am pleased with the increased management and coordination of expertise in the engineering divisions and R&D. The identification of requirements for specialists and experts of all levels is improving. The attention given to developing the skills of their successors is also improving. The introduction of the 'Expert pass' training course designed for the Group's experts is contributing to this.

The transfer of skills and its forward planning, for example when staff retire, needs further improvement, in both France and the UK, using structured methods or pragmatic approaches such as mentoring.

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ROLE OF MANAGERS

Having good knowledge of their teams' skills and further developing them are key tasks for managers.

BETTER ASSESSMENT OF INDIVIDUAL AND COLLECTIVE SKILLS

In the UK, managers ensure that those working on-site or in engineering have the necessary skills for the tasks assigned to them (SQEP approach). They systematically document their assessments and the measures to be taken if skills are not at the required level: prior training, specific support and increased oversight.

In France, managers assess the suitability of staff skills for the tasks more broadly, generally during annual appraisals. Some functions also choose to rely on work situation observations (OST), which provides a good basis for going forward. More generally, EDF and contract partner managers should be in the field more often so that they get to know their teams better in situ and can build professional development programmes.

Training leading to qualification and authorisation is followed by an assessment, but it is not possible to measure the progress of trainees following other types of training. However, training departments at some plants provide managers with an overview of the skills on their site and their opinion. It would be beneficial for this positive approach to be systematically implemented and better use made of it at plant level.

In France and the UK, the shift teams are assessed as part of their authorisation renewal using a few known scenarios. Areas for improvement are documented. I believe this system needs to be made more robust. During Crew Performance Observations (CPO) carried out by WANO every four years, experienced peers assess the ability of shift teams to deal collectively with various normal and accident conditions. This practice should be introduced in all shift teams, using internal resources.

In addition, the local independent nuclear safety oversight teams and the Nuclear Inspectorate rarely assess the training and skills of staff, which are, for example rarely mentioned in the nuclear power plants' annual safety reports. Greater attention should be paid to this.

STRENGTHENING SKILL MANAGEMENT IN FRANCE

The importance attached to skills and the degree of manager involvement vary from site to site.

I have observed some good practices. There are managers that assess the skills of their teams, consolidating the results of assessments and sharing them during annual reviews. Some, when carrying out advanced planning of jobs and skills (GPEC), identify new skills that will be needed, such as system engineering, digitalisation and cybersecurity. Others, who are at an earlier stage, have recently set up an organisation to do this.

On some sites, training committees no longer meet or are not managed at the right level. Advanced planning of jobs and skills is treated as an administrative procedure, and there is no awareness of the connection between skills and performance. Training seems to be primarily seen as a step towards obtaining authorisation.

Leader training in the UK

The rate of absenteeism from training courses is still too high. The attention given to training courses and in-service training varies. Managers rarely attend training sessions unless they are required to do so for authorisation purposes. They often complain that the bureaucratic management of requests for courses and the poor performance of the My-HR training module increase their workload.

DEVELOPING SUPPORT

When I mention the subject of skills, I am often told about macro-processes or course registration. Within the Group, and also for contract partners, working with an experienced person, for example as part of a professional development programme, is an excellent way of developing and consolidating what has been learned on a training course. The same is true of the mentoring practices that have been introduced on a number of sites. Mentoring should be undertaken by managers in the field where possible.

ADJUSTING WHAT IS DONE INTERNALLY AND EXTERNALLY

It is essential for plants and engineering divisions to sub-contract activities in order to deal with variations in workload or to bring in specialist expertise. Greater account should be taken of skills and experience when selecting contract partners, to ensure that the services provided are the required quality. It is essential to give contract partners sufficient visibility of the workload ahead and EDF's medium- and long-term requirements so that they can manage the skill development of their staff.

Keeping certain carefully chosen activities in-house, as has been done by some DPNT and DIPNN departments, has a positive effect on the know-how of business managers, work planners, field supervisors and design engineers. It increases the appeal of their jobs and their authority with sub-contractors. I urge each department to adjust the division between work carried out internally and externally according to the context.

MY RECOMMENDATIONS

Improving the quality of work requires greater emphasis on skills as well as on the management of activities and technical practices. I recommend that the Directors of the DPNT and the DIPNN:

- **Significantly increase manager involvement in the development of team skills**
- **Include contract partners more in training courses for EDF staff.**

The Group needs to attract suitable candidates as well as motivate and develop the skills of recruits. I recommend that the Directors of the DPNT, the DIPNN and EDF Energy enhance career paths by organising mobility between departments, between EPR projects, between France and the UK, and with Framatome.

New training methods using e-learning are being developed. To make sure e-learning is being used correctly, I recommend that the Directors of the DPNT, the DIPNN and EDF Energy assess its scope and how it can be used.

Fire-fighters in action during a drill

Fire represents one of the main risks for nuclear safety.

Controlling the fire risk requires a robust design, rigorous prevention, reliable detection and fire-fighting equipment, and sound preparation for response; this presupposes a strong level of commitment from everyone.

Due to significant engagement and improvements to equipment, progress is clearly visible.

The risk of explosion of flammable gases is taken into account at the initial design stage; perception of this risk is better understood at the plants.

Fire safety: continuing to improve

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THE SITUATION IN BOTH FLEETS

Although the performance of the French fleet declined slightly in 2020, with 8 major or significant fire events and 66 minor events, it has maintained a positive trend over the past few years.

The UK fleet reported no major or significant events in 2020, and the number of minor events fell to 22 (26 in 2019). The indicators of the two fleets cannot be compared directly because events are classified differently.

For many years, the majority of smouldering fires (smoke but no flames) have been caused by electrical faults in both fleets (50% in France and 73% in the UK), as in Europe (52% of the events reported to the WANO centre in Paris).

I urge the fleets to intensify their efforts to improve the reliability of the electrical systems and to stimulate further discussions between the two fleets. The fire prevention week scheduled to take place simultaneously in France and the UK in 2021 should lead to joint initiatives.

MANAGING DESIGN STANDARDS

In terms of fire prevention, nuclear safety is ensured through the compartmentalisation of areas and the separation of systems. Steady progress has been made with design: more detailed assessments of the fire loading of equipment, improved materials for fire doors and plugging, installation of dry risers, more comprehensive modelling of the effects of fire (consequences of smoke and pressure; spread by unburnt gases, etc.) and modifications to prevent certain spurious control system commands in the event of fire (*see Chapter 8*).

In France, the regulatory requirements associated with industrial safety and the environment have been poorly understood for a long time compared with those governing nuclear safety. The efforts underway in this field need to be continued to remedy the situation. Changes to requirements and advances in knowledge are incorporated into specific projects, for example the DPN's Fire Risk Control project and into the ten-yearly outages. During the fourth ten-yearly outage (VD4) of the 900 MWe reactors, new modelling methods were adopted, probabilistic fire risk assessments were carried out for the first time and decisions were made on improvements.

The fire safety committee includes experts and engineering specialists; it has been revitalised through improved coordination by the DIPNN's Technical Division. Its aim is to take better account of technical and regulatory knowledge and to harmonise the standards.

In the UK, the initial design of the older AGRs did not include the complete physical separation of systems and the safety case is more biased towards fire suppression measures. Over the years, modifications have been made that strengthen the design. These include the installation of partition walls, updating the fire suppression systems, and improvements in the fire resistance of buildings.

The design of the UK's EPRs incorporates specific requirements from the regulations, e.g. taking aggravating factors and accumulated events into account, and the provision of safe areas in front of staircases (lobbies).

FIRE PREVENTION: THE MOMENTUM MUST BE MAINTAINED

Fire load management is improving, but as identified in my previous reports, it still remains a concern. Staff do not know enough about the real constraints associated with fire loading. Compartmentalisation studies can be used to estimate the fire duration based on the fire loading. However, sites find them difficult to use as there are no room-by-room views. I am pleased to see the good idea of one nuclear power plant to revise these studies to incorporate fire loading limits and the location of storage areas in each room.

In the UK, to meet nuclear safety requirements, the maximum fire loading volume that can be stored in each room or area has been calculated. Compliance with this limit must be ensured when any work is carried out in these areas.

However, as in France, staff do not take sufficient account of these requirements. EDF Energy has recently introduced an Intranet application for controlling temporary storage areas, from the request through to approval by the fire safety coordinator. This good practice has led to significant improvements being noted, particularly during statutory outages.

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Four significant fires

Between January 2015 and December 2018, the WANO Paris centre identified four significant events reported by its members, including three at EDF:

- A titanium fire broke out during the re-tubing of a condenser whilst using a plasma torch, without adequate risk analysis.
- Eight alternator excitation cabinets were destroyed during maintenance work. The fire lasted for one and a half hours. These cabinets had been previously affected by a similar fire.
- A fire in an inverter power supply cabinet caused a spurious automatic reactor trip and safety injection. The causes were identified as inadequate preventive maintenance and ageing equipment.
- An electric arc resulted in the destruction of an alternator stator, leading to a 134-day outage. The cause was the incorrect assembly of a bolted connection.

At the DPN, maintaining compartmentalisation is a point that still requires attention but the situation is improving. The standard for fire areas with major nuclear safety implications (there are 5 such areas, representing 60 to 70 rooms per reactor) requires rigorous and exemplary application of the fire prevention rules. The DPN Nuclear Inspectorate observed fewer issues. Floor drains play a part in compartmentalisation provided that their water seal traps are kept at the correct level. However, this aspect is insufficiently integrated into the culture and the organisations.

FIRE-FIGHTING IS IMPROVING

The facilities are designed so that, in the case of a fire, nuclear safety is preserved through the provision of physical measures that are sufficient even in the absence of the fire brigade. However, the development of a fire must be controlled in order to limit its consequences on nuclear safety as well as on industrial safety, the environment and assets.

In France, if the fire is small and provided that it is safe to do so, the EDF response teams try to extinguish it before it spreads. If the fire grows, their role is essentially to contain it, while the fire brigade officers take over extinguishing the source of the fire.

The EDF response teams have improved considerably as a result of training and drills. In the operations department, the shift industrial safety officers have generally assimilated their role as leaders of the fire response teams. New recruits have a good understanding of the challenges involved in fire-fighting. The training courses provided by the Fire Safety & Prevention Training Institute (IFOPSE) are very practical, good quality and positively received. Two plant operators instead of one will now be mobilised in the event of an alarm; this will enhance safety and facilitate a rapid initial response, often seen to be a determining factor.

However, I note that the emergency response managers do not always have sufficient fire-fighting expertise to support the emergency response team leaders. Their training programme consists of an initial one-day module and three-yearly refresher modules organised by IFOPSE, but the emergency response managers never find time to complete it because of their professional obligations. It would be worth looking out how to adapt this programme.

Fire-fighter training at IFOPSE

Joint drills with the local fire and rescue services are organised in the nuclear power plants. The response times of the local fire and rescue services depend on the site and the circumstances. In fact, most of their teams are made up of volunteer fire-fighters, whose numbers and availability during working hours can vary. I am pleased to see the DPN's recent commitments to improving the organisation of fire-fighting by:

- Avoiding calling out the local fire and rescue services unnecessarily (up to 39 calls in one year by one nuclear power plant), by carrying out an initial verification on the extent of the fire (within a maximum time limit).
- Having teams of EDF volunteer fire-fighters on-site during working hours who are capable of supplementing the local fire and rescue service teams.

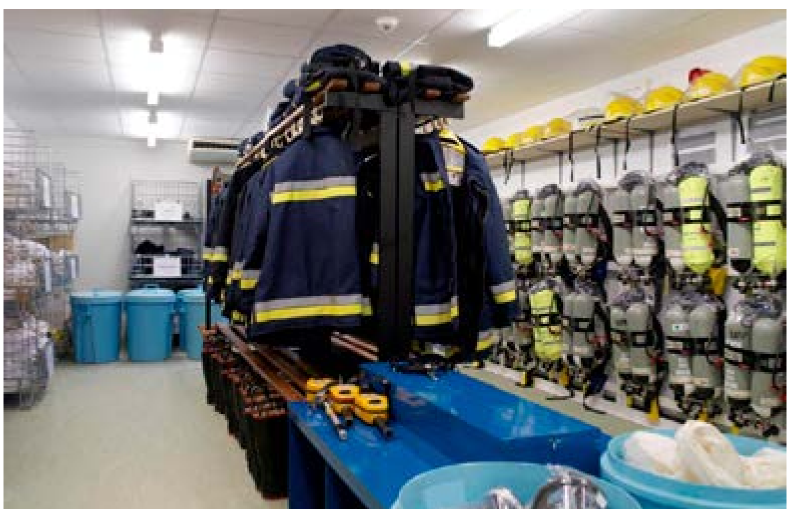
I urge the DPN to increase communication with the local fire and rescue services to ensure compliance with response times and so that specific geographic features can be dealt with constructively.

Fire Safety & Prevention Training Institute (IFOPSE)

This institute was established in 1983, with training courses inspired by the French Navy methods. It became a subsidiary of EDF SA in 2009. Although EDF represents 60% of its business, IFOPSE also works for other high-risk companies and lends its facilities to the fire-fighters of the local fire and rescue service in the Morbihan region. A total of 28,000 trainees attended its courses in 2019. All operating staff go there for a week's training every two years.
Its engineering activities are expanding, particularly for Hinkley Point C.
It has two operational centres, in La Roche Bernard and Les Avenières, which both have very comprehensive facilities. They can now offer more realistic scenarios, e.g. in a nuclear auxiliary building environment. There is also a turbine hall mock-up covering several floors.

In the UK, the operating staff are trained, drilled and qualified to carry out direct fire-fighting for the first hour or until the local fire brigade arrives. These arrangements allow for a rapid response, even in the case of major outbreaks of fire.

Most plants have their own training arrangements. Drills are carried out in real heat and smoke conditions and include wearing breathing apparatus (BA) and using on-site fire-fighting equipment. Professional fire-fighters often attend these drills.



Fire-fighting equipment for emergency responders in the UK

In 2020, EDF Energy Nuclear Generation produced a booklet to help the public emergency services understand the specific features of fire-fighting on its nuclear plants. It describes the plant's emergency organisation and the risks specific to working in controlled areas. I support this approach, both as a training aid and a memory aid for use by all external emergency service personnel, many of whom do not have sufficient knowledge of the station layout.

BETTER CONSIDERATION OF GAS EXPLOSION RISKS

The 'internal explosion' hazard concerns leaks of hydrogen used to cool the alternator and, in pressurised water reactors, to regulate the chemistry of the primary cooling system. Hydrogen may also be released from batteries. In AGRs, the methane used to protect the graphite moderator is also a potential source of explosion. These gases are stored in bottles and circulate inside and outside the buildings.

In France, the explosion of flammable gases is considered in two ways:

- As an internal hazard from a nuclear safety perspective
- As an ATEX hazard (regulations governing explosive atmospheres) from an industrial safety perspective.

These two risks are covered in two complementary sets of regulations. It is appropriate that EDF SA has initiated studies and is devoting considerable resources to bring itself up to the required level, albeit somewhat belatedly.

EDF SA is conducting a large number of studies on how these risks can be better taken into account, particularly in the context of the VD4 900. For example, the assumptions regarding the location of leaks in the systems have been reviewed: from now on, leaks are considered to affect all parts, not just at removable pipe joints. The consequences on nuclear safety have been analysed and probabilistic nuclear safety assessments carried out. Where necessary, the list of high-risk areas has been reviewed and modifications have been made to facilities, procedures and oversight programmes.

Inadequate regulatory monitoring has meant that changes to requirements have not been anticipated. For example, the refurbishment of turbine halls, which took several years to complete, could require additional work to incorporate the latest regulatory changes. Nevertheless, each plant has updated its Document on Protection Against Explosion (DRPCE).

In the UK, as in France, the nuclear safety consequences of a fire are continuously analysed as part of ongoing periodic safety reviews, which can lead to either modifications or procedural changes. Industrial safety aspects are set out in the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR). Following

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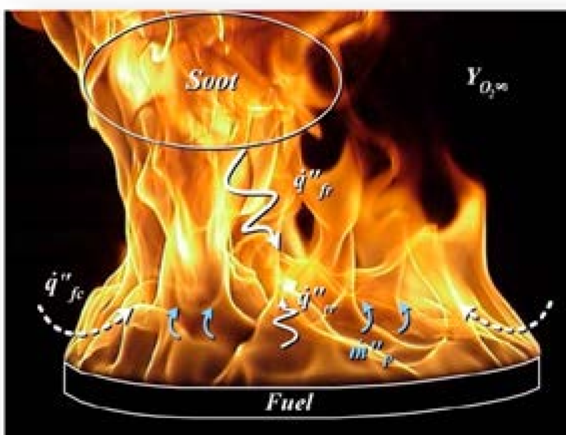
an external audit on building compliance with respect to these regulations initiated by EDF Energy, 1,600 non-conformities were detected across the fleet. Priority actions were carried out. I urge EDF Energy Nuclear Generation to resolve all outstanding issues with appropriate modifications or justifications with the current position.

Workers in both fleets apply the same safety protections prior to entering an explosion risk zone such as; wearing protective equipment, carrying a detector and using spark-free tools.

It would appear that there is currently a better understanding of the risk of explosion from both a nuclear safety and an industrial safety aspect. The progress made in the fleets must now be completely integrated into the design studies for future new-build projects; this should be done by reducing the volume of explosive gases in buildings, the pipe lengths, and the number of explosion areas.

AN AMBITIOUS RESEARCH AND DEVELOPMENT PROGRAMME

A great deal of work is being carried out by EDF R&D in the fields of fire and explosion.



Flame modelling at the EDF R&D laboratory

The 2021 fire project is ambitious and involves a high number of experts. Its aim is to assess: the effects of pressure on fires, the production and impact of soot on equipment, the physics of confined fires, etc. It has substantial resources and is developing high-level modelling techniques. It has excellent test facilities in terms of material, components and full-scale mock-ups.

EDF R&D has developed several widely recognised numerical codes such as: Magic for characterising and modelling fires, and Saturne for large volumes and complex geometries. The Ignis experimental facility, which is due to be commissioned in 2021, will enable full-scale testing. It is involved in numerous collaborations with other research centres.

The 'explosion prevention' project launched in 2020 should help to improve the modelling of hydrogen dispersion and transfer. It uses the FLACS (Flame Accelerator Simulator), a commercially available computer code that has become the standard tool. Collaborations with centres of expertise have also been initiated.

FIRE SAFETY MANAGEMENT: A PILLAR TO BE CONSOLIDATED

Each site must maintain high fire safety standards. This requires constant effort from managers and staff: everyone has individual responsibility for ensuring that fire safety is controlled effectively.

In France, the on-site fire teams usually include the fire safety supervisor, the area supervisor and the fire brigade officer. The advance planning of the jobs and skills of fire safety supervisors is a sensitive point: the pool of staff wanting to undertake this role is small and regularly results in young, inexperienced engineers being appointed.

In EDF SA, the fire culture has improved, particularly in the new generations of shift teams. The fire brigade officers consider the EDF culture to be better than what they have seen in other companies. It would be encouraging to see the same impetus from contractors.

I would like OPEX to be more proactive, particularly in terms of organisation. The DPN still too frequently reacts to the ASN's demands rather than being sufficiently proactive to take advantage of the analyses of significant events. For example, the hydrogen fire that occurred in a gas storage area at a nuclear power plant in 2020 has still not been included in the training courses.

The fire safety approach (schéma de sécurisation) is based on a self-assessment table containing 24 items used to compare against the three themes: organisation, professional actions, and equipment. This complexity and desire for completeness means that only a minority of staff can use it. I suggest it be simplified, focusing on actual performance.

In my previous reports, I stressed that the risk of fire was not adequately taken into account on the Flamanville 3 construction site. I am pleased to see that substantial progress has been made. Awareness is clear to see, and the fire safety team is regularly called on for support. Flamanville 3 has also ten volunteer fire-fighters, as well as an emergency and fire centre manned by the site's volunteer fire-fighters, which is operational across Flamanville 1, 2 and 3.

In the UK, the Fire Safety Fleet Manager coordinates the continuous improvement of the fleet. At plant level, a fire safety coordinator manages the implementation of standards, and engineers are responsible for the fire detection and suppression systems whose reliability has improved. Plant housekeeping is also continuing to improve.

Fire system engineers need support from the central engineering function to deal with safety cases and modifications. However, given the workload at the centre, this support is often delayed. The 'fire systems' user group, in which good practices and expertise are shared, does not meet often enough. I look forward to there being more frequent meetings.

The role of the fire safety action team (FSAT) at each site is to act as a catalyst for fire safety, bringing together all those involved. The most effective fire safety committees are generally chaired by a member of the management team. I urge all sites to follow suit.

Fire safety performance is assessed using a composite indicator, known as the fire safety focus index (FSFI). To gain a better understanding of the situation, I suggest that the index be updated to include storage areas with non-compliant heat loads, and the total number of oil leaks, whose numbers are still too high.

MY RECOMMENDATIONS

In order to improve fire risk management, I recommend that the Directors of the DPN and EDF Energy Nuclear Generation focus on:

- **Good control of fire loads in France and the UK**
- **Rigorous fire compartmentalisation in France**
- **Availability of fire detection and suppression systems in the UK.**

For the past few years, the majority of fires in both fleets have been caused by electrical faults. I recommend that the Directors of the DPNT and EDF Energy Nuclear Generation increase their focus on electrical equipment.

In France, improving the organisation of fire-fighting will require more on-site volunteer fire-fighters and increased coordination with the local fire and rescue services. I recommend that the Director of the DPN actively promote volunteering, targeting young recruits in particular.

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Contractors - Gravelines nuclear power plant

EDF subcontracts a majority of its maintenance and modification work due to the seasonal nature of maintenance outages and the specialist expertise required for some work. The same applies to engineering activities.

The many issues encountered over the past few years with the quality of subcontracted services (design, manufacturing, construction and maintenance) demand the revision of the surveillance procedures.

Improving the technical aspects of surveillance 07

Surveillance carried out under the responsibility of the Operator does not exempt contract partners from carrying out their own oversight.

In France, the regulations, the ministerial order on quality and the ministerial order on licensed nuclear facilities (INB), stipulate surveillance of all contractors carrying out activities important for nuclear safety.

The regulatory contexts and the levels of accountability of subcontractors are different in France and the UK.

AT THE PLANTS: ACTION PLANS FOR NON-CONFORMITIES

SURVEILLANCE HAS STILL NOT REACHED TECHNICAL MATURITY…

Many initiatives have been implemented throughout the Group to help improve surveillance.

Surveillance plans are drawn up routinely, based on the results of project risk analyses and OPEX, including sub-standard maintenance work.

In France, the Argos application, available on tablets and recently deployed at plants, enables users to create surveillance programmes from a library. With it they can take photographs, enter comments and annotate documents. It is popular with users, improves surveillance and makes it easy to produce reports.

The guidelines for operational maintenance and project management (MPPE) define the roles of surveillance officers, business managers, and business and project managers. Coordination networks for those involved in surveillance promote the sharing of good practices. However, the multiplicity of people involved weakens the chain of responsibility: surveillance officers want support for drafting surveillance plans, business managers have a great many administrative tasks to deal with, and business and project managers focus on meeting deadlines. The site joint project teams[18] have chosen another model in which the surveillance officer and business manager roles are merged.

Recent recruits have injected new blood into the surveillance teams, but they have not always acquired the necessary experience in their careers to perform their roles effectively. Some plants have decided to bring some activities back in-house in order to strengthen the technical management of staff. This seems to be an appropriate initiative, and is welcomed by EDF staff and contract partners alike.

Over the past few years, irregularities, varying widely in their nature and importance, have been detected. The main non-conformities concern technical inspection or surveillance points shown as having been completed when this is not the case. Various action plans have been initiated, and have produced the required effects when drifts have occurred. I recommend that their implementation continue.

Management of irregularities

Following the discovery of non-conformities, the DIPNN's Industrial Division defined an organisation to deal with CFSI (counterfeiting, falsification and suspicion of irregularities) and representatives have been appointed on all plants. A collaborative workspace has also been set up, to bring all the reference documents together in one place and capitalise on OPEX. The training courses and vocational academies will be updated. Surveillance officers, shift managers and safety engineers will also be trained.

In the UK, surveillance on the plants is managed by the Contract Managers with respect to all main contract partners. Reporting to the supply chain and coordinated by a corporate department, their aim is to build a constructive relationship with all subcontractors. As in France, the level of surveillance depends on the type of work and the risk. Contract Managers ensure that permanent subcontractors have their own field supervisors who will control the activities of their own staff, including conducting their own surveillance of nuclear and industrial safety, procedural compliance and quality assurance. Contract Managers are regularly present in the field, frequently with subcontractor management teams, ensuring that field supervisors are fulfilling this role correctly and will share their observations. However, these visits would benefit from focusing more on the technical aspect of work carried out, rather than solely on industrial safety and working conditions.

For other contracts, the field supervisors from the site maintenance teams will monitor their work day to day. They can also lift hold or witness points depending on their qualifications.

18 *Mixed engineering and plant teams responsible for implementing modifications on site (équipes communes)*

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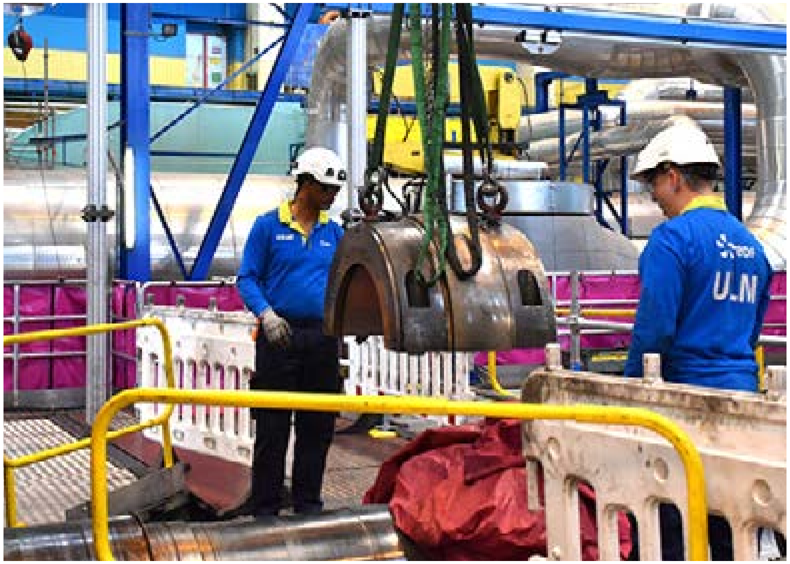

ULM workers

The project department, which is responsible for modifications, has its own field supervisors and contract managers. However, the contract managers in this department do not have the same level of training and qualifications as those in the Supply Chain department. I would like this to be remedied within a reasonable period of time.

All field supervisors, whether they are EDF Energy staff or contract partners, are trained and qualified to the same standards; this includes being authorised by the site maintenance manager.

… AND THERE IS SOMETIMES AN IMBALANCE BETWEEN WORKLOADS AND RESOURCES

Surveillance officer staffing does not take sufficient account of the overlapping of outages or the increasing number of activities with units in service. Some professions, such as valve and heavy maintenance, seem to be having more difficulty. Furthermore, the working hours of surveillance officers do not always fit in with work organised in extended or weekend shifts. Some business managers find it difficult to manage the high demand for preparation work, such as packaging or work in controlled areas.

The Maintenance & Logistics Unit (ULM) has developed robust surveillance capabilities, both in terms of volume and expertise. Surveillance officers are also expected be able to perform the activities they are required to oversee. I support the synergies that are developing with the nuclear power plants to improve the quality of surveillance on the sites.

THE SURVEILLANCE OF DESIGN REQUIRES FRESH IMPETUS

The engineering functions monitor the activities of design offices and equipment suppliers. Subcontracting is increasing, the subcontracted work is multi-disciplinary and the integrated design groups are expanding. Coordination between various functions (EDF engineering divisions, Edvance, subcontractors, Framatome, partner engineering companies, etc.) is changing, and surveillance must adapt to this change.

The objective of risk assessments, which are expanding, is to build targeted surveillance programmes focusing on points identified as being the most sensitive and to make use of skilled teams. This is all the more important as the surveillance programmes sometimes lose their meaning and become too procedure-based. Lessons should be learned from the difficulties encountered at Flamanville 3, such as the non-conformity of the CCWS/ESWS heat exchangers.

I think that the ‘product owners’ introduced by the DIPNN (*see Chapter 9*) have a role to play. Their knowledge of products, OPEX, industrial capacities, etc. could enhance risk assessments and the relevance of surveillance programmes.

Surveillance is not a full-time role: engineers perform this activity as part of their general duties. This approach is positive as it better integrates the technical aspect into surveillance, but it sometimes comes up against a lack of experience. I recommend continuing the training initiatives and actions introduced to improve surveillance procedures and guidelines. Bringing certain design activities back in-house, even temporarily, should also help to reinforce the skills of staff involved in surveillance.

MANUFACTURING: INSPECTIONS IN THE FIELD

In my last report, I highlighted the work carried out by the DIPNN’s Industrial Division to improve the surveillance of manufacturing. This continued in 2020.

Two of the five cornerstones of the *plan excell* (*see My view*) set out to expand lists of suppliers so that products are “right first time”, and also to change partner relations to make them more result-oriented. GIFEN is involved in this.

THE PRINCIPLES ARE CHANGING

I believe it is necessary to continue towards increased surveillance of the manufacturing processes. I realise how difficult this is, given that the manufacturer may also have other clients; some of these processes may have been in place before EDF contracts. I suggest that surveillance pay more attention to supplier processes, taking care not to violate intellectual property rights and confidentiality rules.

The organisation of surveillance involves a large number of people: the project team signs off the surveillance programme, the engineering department manages the technical aspects of the contract, the Industrial Division conducts the surveillance and records its findings, the manufacturer (and its various entities) carries out or subcontracts the manufacturing and inspections of the part, and the purchasing division is responsible for contract management. It is important to ensure that this complexity does not dilute responsibility.

To improve manufacturing quality control, the Hinkley Point C project has decided to stop relying solely on tier 1 suppliers to conduct surveillance of tier 2 or 3 suppliers. Instances of defective quality control on liners and tanks confirm the relevance of this decision. I note that the Independent Nuclear Assurance (INA) has also started to monitor lower tier suppliers.

SURVEILLANCE IN FABRICATION PLANTS AND THE TECHNICAL ASPECT: TWO PRIORITIES

EDF SA sometimes draws up specifications, which are too strict and do not take sufficient account of industrial feasibility. Ultimately, this leads to the situation where there is little chance of obtaining equipment that meets the requirements. The recent modification of an electrical cabinet cooling device in the 1300 MWe fleet illustrates this issue. Along the same lines, some equipment suppliers contacted by Hinkley Point C initially declined to tender in the light of the strict specifications.

Turbine rotor shaft checks - Heysham 1 nuclear power plant

To ensure the industrial feasibility of these generic specifications, the DIPNN's Technical Division is involving suppliers in the process and updating the engineering standards (RTI 2). The successful procurement of boiler steam stop valves for an AGR, even though this product had not been made for several decades, confirms the benefit of working closely with suppliers.

Surveillance at Flamanville 3

With regard to manufacturing for Hinkley Point C, the Framatome quality improvement plan started in January 2020. Its actions must be implemented fully in the field. The Office for Nuclear Regulation (ONR) is also very interested in this and is using the INA for some of its observations. The DIPNN's Industrial Division is increasing surveillance of all manufacturing.

The decline in the skills of some suppliers, particularly in the fields of heavy maintenance, pipework and valves, means that increased surveillance is required, which calls for sound technical skills. I have been told that in plants, there is a lack of people with the required profile to be an inspector.

The nuclear safety culture at supplier organisations also requires support, in order to maintain awareness of the issues and requirements of the nuclear industry. I support the initiative of one of the DIPNN's departments that is planning to introduce training courses on nuclear safety culture for its suppliers.

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Procurement of a steam valve

The main steam boiler inlet valves on an AGR had to be replaced. However, they had not been made since the mid-1960s. From September 2019 onwards, numerous technical discussions were organised between EDF Energy's experts and the manufacturer. The new design of the valve, devised jointly, minimised changes to the original design while incorporating the new nuclear safety requirements and the current manufacturing codes. Eight valves were ordered, with the first ones due to be delivered in January 2021. Monitoring of all stages of manufacturing was increased.

PROGRESS IN CONSTRUCTION AT HINKLEY POINT C

Better surveillance would doubtless have meant that some assembly defects on the Flamanville 3 construction site would have been detected earlier. Based on this experience, the Hinkley Point C project has incorporated significant changes to improve detection of non-compliances. For example, more than 60 inspectors are available on-site 24 hours a day, 7 days a week. Inspections are conducted using a graduated approach based on risk.

Rebar surveillance at Hinkley Point C construction site

I note that the number of field change requests (FCRs) and non-conformance reports (NCRs) is continuing to increase, despite the efforts of the Joint Design Office (JDO)[19]. This is still causing a bottleneck in the validation process. Many of the FCRs are minor and result from delays in the provision of final drawings, which prevent contractors from carrying out the correct preparations. I am pleased with the work that has been initiated by Hinkley Point C to give some contractors greater autonomy in resolving these changes themselves.

Electrical cabinet checks - Bugey nuclear power plant

RELATIONS WITH CONTRACT PARTNERS

Surveillance cannot make up for all the shortcomings of a supplier. However, it is preferable that it is conducted in a climate of trust. I highlighted the positive effects of greater involvement of contract partners in my 2017 report. This can be seen in the UK, which is helped by the different legislative context compared to that in France.

In the UK, main (or 'permanent') contract partners play a full role in the plant's life and its management teams. They receive the same training as EDF Energy staff, including courses on leadership and human performance. They are involved in shared field visits and are fully integrated in the 'Leaders in the field' programme.

[19] *On-site engineering team for quick resolution of problems encountered during construction*

In France, I have observed various practices that are bringing about improvements:

- The first VD4 900, carried out at Tricastin, owes part of its success to the significant involvement of contract partners during the preparation and execution phases.
- There is some regional coordination of contract partners and EDF, but its scope is limited.
- The PCC-EO and PIRP departments of the DPN are working on the convergence of EDF and contract partner training courses (see Chapter 5).
- Some sites organise a weekly meeting between the contract partner management and plant management.
- The pandemic has also helped build stronger links between EDF and its contract partners, which are appreciated (see Chapter 2).

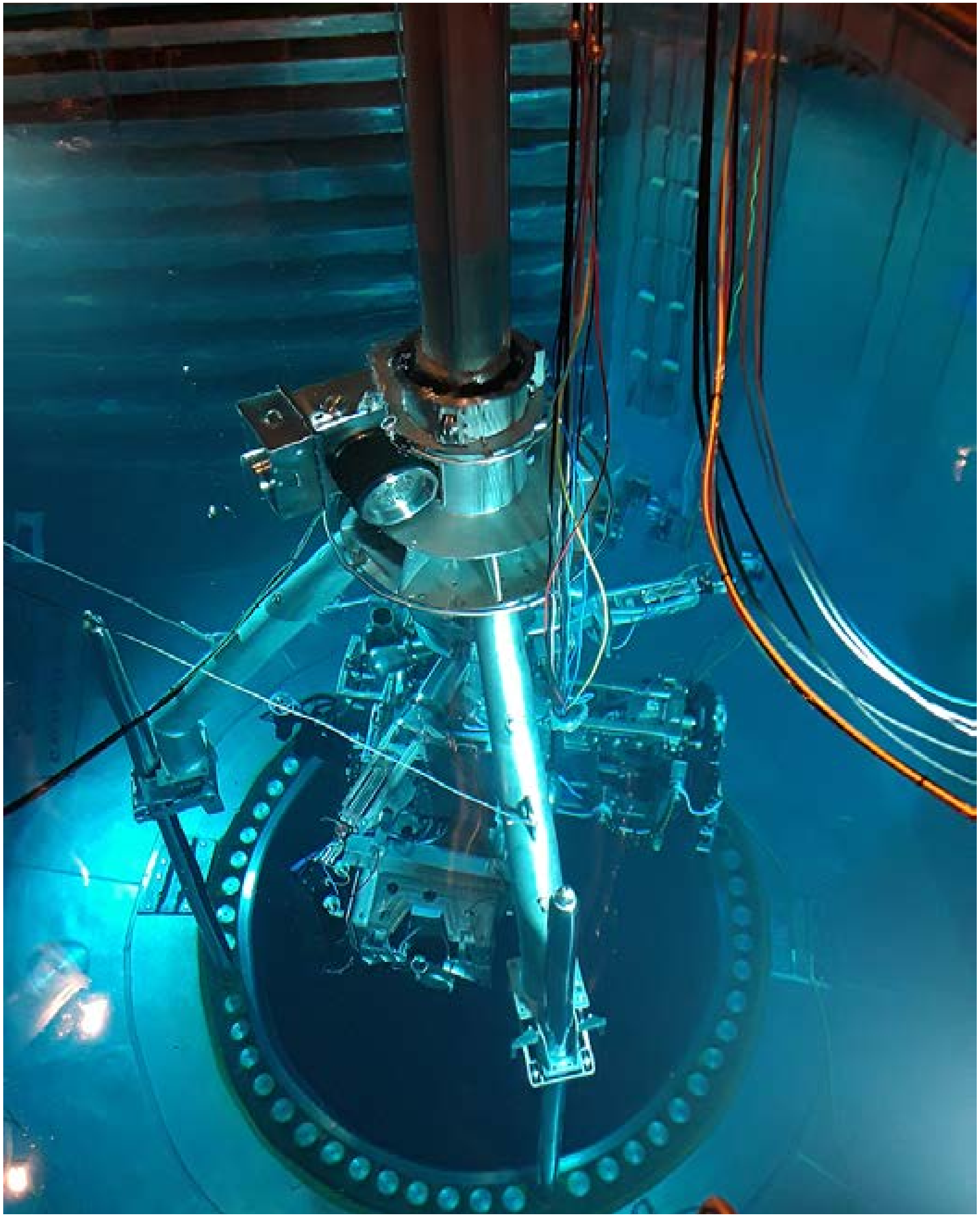
The legislative context in France does not permit contract partners to be fully integrated into EDF SA's teams. It does not, however, forbid a partnership-based approach with suppliers, which is not always taken to its full potential. I suggest that initiatives continue and every opportunity be sought to build lasting partnerships.

MY RECOMMENDATIONS

Considering how important the technical aspect of surveillance is, I recommend that the Directors of the DPNT, the DIPNN and EDF Energy:

- **Finalise integration of the technical aspects into surveillance performed at fabrication plants**
- **Adjust and manage the balance between work carried out internally and externally to strengthen the technical expertise of field supervisors on-site and in the engineering functions.**

A climate of trust creates conditions conducive to high performance and high quality. I recommend that the Directors of the DPNT and the DIPNN develop partnerships with contractors in this context where there is a considerable industrial workload.



Reactor vessel in-service inspection machine - Tricastin nuclear power plant

The French fleet is committed to an extensive reactor safety improvement programme.

Tricastin and Bugey are the first to have completed their 4th ten-yearly outages (VD4), undertaken after 40 years of operation.

This major programme is pushing everyone - engineering teams, sites and contractors alike - to the limit. The situation is compounded by the fact that the fourth safety review and VD4 outages for the 900 MWe fleet are overlapping with completion of the VD3 outages and preparations for the fourth safety review in the 1300 MWe fleet, as well as with completion of the VD2 outages and preparations for the VD3 outages in the N4 fleet.

VD4: unprecedented efforts for nuclear safety 08

This chapter covers the fourth periodic safety reviews for the French fleet. The British fleet - namely the AGRs and the Sizewell B PWR - are discussed in Chapter 3 and My view.

VD4 OUTAGES FOR THE 900 MWE FLEET

PWRs demonstrate excellent robustness and high stability, so naturally like in many other countries, it makes sense to plan to operate these facilities for a long time. The original design assumption for the lifetime of certain equipment was 40 years, so EDF and the ASN earmarked the VD4 outage milestone as an occasion for additional compliance checks and safety improvements. Post-Fukushima modifications underpin the review and are also being incorporated.

These VD4 modifications have been divided into packages to even out the studies and the workload. For the 900 MWe fleet, the majority of the safety modifications are being completed during the ten-yearly outage as part of a first package; a second package will be carried out two years later; a potential additional package will incorporate any modifications agreed a posteriori at the standing group meetings[20]. This additional package will be combined with the second package for all VD4 outages after 2025.

COORDINATED ACTION

Ownership of the ten-yearly outages and modifications now lies with the DPN. A dedicated fleet upgrade programme (known as the Grand Carénage, or GK) is handling the project management side. The relevant engineering functions (DIPDE and CNEPE) implement the modifications on-site. A VD4 900 directorate, chaired by the DPNT Director, is tackling several challenging issues concurrently with success. The GK programme has brought a great deal of clarity to proceedings, as well as to the coordinated management of projects and engineering teams.

Technical decisions are guided by the Design Authority (DESA) which is providing valuable support and ensuring consistency. There has been a significant improvement on the engineering side, which is now more Operator-centred and aligned with GK priorities. This has contributed to the success of the first-in-series VD4 outage at Tricastin. However, timely drafting of site documentation by DPN corporate services and engineering teams is still proving difficult.

R&D is providing a considerable amount of support for the safety review. I would like to highlight the quality of their facilities and work, examples of which include the IGNIS experimental facility (see Chapter 6), work on sump filters at the Chatou laboratory (including a mock-up of the reactor basemat), the Vercors experimental facility (1/3 scale mock-up of a 1300 MWe reactor containment), the experimental loop for simulating steam generator tube fouling, and material ageing tests at the Renardières laboratory. Similarly, the TEGG[21] department has developed composites for containment sealing in the 1300 MWe fleet and concretes to protect the basemat in the event of a severe accident.

Ten-yearly safety reviews and outages

In compliance with international standards, the Group conducts periodic safety reviews of its reactors every ten years. These serve a dual purpose:

- To verify reactor compliance with the safety report and applicable safety standards
- To examine reactor safety with respect to OPEX, the latest knowledge, technological advances and the measures incorporated into the newest reactors.

Every safety review conducted in France to date has led to significant improvements. The safety reviews consist of a generic phase relating to the standard model in each series and a dedicated phase for each reactor. This is linked to each ten-yearly outage (VD), during which the majority of checks (typically including vessel inspections, hydrostatic testing of the primary system and containment tests), compliance recovery actions, and modifications are completed.
In the UK, the objectives for each safety review are agreed with the ONR for all reactors. The actual review of the AGR fleet is then conducted for each reactor pair, as the designs vary from one plant to another. The bulk of AGR modifications were made during the first and second periodic safety reviews. The third review, which has just been completed, took a more holistic review of safety by taking into account existing processes and human factors.

[20] *Standing groups of experts set up by the ASN*
[21] *Construction techniques and expertise in civil engineering and geosciences attached to the DIPNN's Industrial Division*

The examination of the safety review with IRSN was extremely onerous and of a very high technical quality. Several dozen additional modifications were nevertheless identified at the end of the review; although some of these appear to be justified, it raises the question as to why so many were identified at this stage of the review process. The ramifications in terms of increased workload are also impacting the studies for the fourth review of the 1300 MWe fleet.

A public consultation proposed by EDF was conducted under the aegis of the HCTISN[22] prior to the public enquiries planned for each VD4 outage. This process seems to have satisfied all interested parties. The local meetings saw a high level of public participation. This process will be replicated for the 1300 MWe fleet's fourth periodic safety reviews.

EXTENSIVE EFFORTS TO INSPECT FACILITIES AND EQUIPMENT

All reactor equipment can be replaced except for the pressure vessel and containment. Every ten-yearly outage involves inspections of: the vessel (by ultrasonic testing and radiography), containment (leaktightness test and investigation), and a large number of equipment.

Turbine hall - Bugey nuclear power plant

The steam generators are always subject to extra scrutiny which could include; in-service testing, deposit modelling, chemical cleaning or replacement. The need to meet the replacement programme deadlines is a given as far as I am concerned.

There is also a programme to check and replace, where necessary, the cast elbows on the primary cooling system, which are known to be susceptible to thermal ageing. Some of them between the reactor vessel and the primary cooling system are known to be nearing end-of-life, but cannot be replaced due to the high dose rates. Methods for more precise testing and potential thermal heat treatment must be continued with vigour.

I am pleased to see that the VD4 outages include inspections of areas where no degradation is expected, specifically - and for the first time - the fuel assembly transfer tube between the reactor building and the spent fuel pools. So far, the first ten-yearly outages have not revealed any particular issues in these areas.

Following a number of non-conformities detected in recent years, the VD4 outages include a major programme to identify and resolve any additional non-conformities (in relation to anchors, support structures, bolted assemblies, electrical relays, protection against external hazards, etc.) which will significantly consolidate reactor safety. A broad sample of equipment, electrical components and cables has also been taken over recent years to assess ageing.

The equipment was originally qualified for accident conditions for a period of 40 years. The purpose during the VD4 outages is to either demonstrate their qualification for life extension beyond this time (usually the case for metallic components) or to replace them (e.g. some electrical components).

Demonstration to confirm that the sump filters will not clog with insulation or paint debris in the event of a break in the primary system is well on the way to being substantiated for all situations; this is a positive step. This is a result of modifications implemented in the 2000s (notably a tenfold increase in filter surface area), as well as the testing, modelling and decision to replace the most sensitive insulation.

MAJOR SAFETY ENHANCEMENTS

The VD4 outages involve a large number of safety studies:

- Review of all the transient and accident studies based on the most recent methods and knowledge of the physical phenomena
- Review of the internal and external hazards, specifically: flooding, fire, explosion (*see Chapter 6*) and extreme weather conditions
- Extension of the scope of probabilistic safety assessments to fire, earthquake, flooding, and explosion.

These studies are helping to increase the depth of understanding in reactor technology, strengthen the safety report and refresh nuclear

[22] *High committee for transparency and information on nuclear matters*

safety knowledge, all of which is extremely positive. Measures to protect against internal and external hazards, particularly weather-related conditions (flooding, frazil ice, extreme heat, etc.), has improved as a direct result, and marks real progress.

The following major modifications are considerably strengthening defence in depth:

- Ultimate diesel generators, which significantly improve safety in the event of a total loss of off-site power. I am pleased that this project is now complete, having fallen behind schedule
- The addition of an emergency water source (pumped from groundwater or surface water reservoirs) to mitigate against a total loss of heat sink
- The addition of a new cooling train for the spent fuel pool.

Spent fuel pool

The spent fuel storage pool and building have been the subject of an in-depth review encompassing:

- Transient and accident scenarios (like the reactor)
- External hazards (fire, internal and external flooding, explosion, earthquake, aircraft crash)
- Drop of transport cask in the spent fuel building
- Probabilistic safety assessments.

Modifications have been planned where deemed necessary, such as the addition of the following:

- A fuel pool make-up water system (with an emergency source of water) to ensure cooling by boiling and evaporation in the event of a total loss of all other cooling systems
- An additional fuel pool cooling system with a pump and a mobile heat exchanger.

The complete revision of the safety analysis and resulting modifications greatly improves the nuclear safety of the fuel storage pool.

To maintain containment integrity and to keep releases to a minimum in the event of a core meltdown, the VD4 outages include provision for:

- A dedicated cooling system to avoid opening the containment venting system, which will be kept and reinforced to withstand an earthquake
- A passive corium spreading area and flooding device to prevent basemat melt-through.

Additionally, the Nuclear rapid reaction force (FARN) and its mobile units can provide electricity, water and the necessary cooling resources in all circumstances.

SPECIFIC SCHEDULING OF ACTIVITIES FOR VD4 OUTAGES

The specific nature of the VD4 900 outages is visible in the high volume of work (around five times more than the VD3 outages taking all packages into account) and the fact that the bulk of the work is conducted while the unit is in service. For instance, many of the pipes, electrical cables and equipment are installed whilst the reactor is operating and then connected up during the subsequent ten-yearly outage. It is also reflected in the amount of electrical work; a third electrical power line nested in the two existing systems is being installed in order to connect the ultimate diesel generators to the site equipment. The logic sequence of tagging, connecting and switching of power supplies during the ten-yearly outages is extremely complex.

Preparatory work such as laying cables, installing raised access floors, unplugging wall and floor openings, etc. is also carried out in sensitive electrical facilities whilst the reactor is at power prior to the ten-yearly outages. Thanks to rigorous preparation and monitoring, this was completed without incident at Tricastin and Bugey. I call for the same level of vigilance regarding compartmentalisation, control of fire loads and electrical cabinet protection during the 30 remaining ten-yearly outages.

Engineering activities at the DIPDE

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Tricastin nuclear power plant

The first-in-series VD4 900 outage at Tricastin ran smoothly. This success was attributable not only to the enormous amount of preparatory work, but also to the collective effort in reducing silo mentalities, aligning objectives and establishing a much closer relationship between engineering functions (joint site teams and the DIPDE) and the plants.

The second of the VD4 ten-yearly outages took place at Bugey, which also went very well. This was thanks to the ownership from site staff to achieve their common goal. However, the discovery (outside the scope of the outage) of cracks on the front tank of the effluent system has extended the outage considerably.

OPEX TO PREPARE FOR THE NEXT TEN-YEARLY OUTAGES

After these first 2 VD4 900 outages, there are 30 more to follow and the pace of these has to be maintained over a long time. This is even more critical given the impending additional modification packages and the VD4 outages for the 1300 MWe fleet. The workload from both a Group and contractor perspective is a matter requiring particular attention (*see My view*).

Standardisation of the VD4 outages is therefore a must so that the documents, methods and schedules from the first-in-series outage can be applied across the fleet. The DPN has launched a project to tackle this issue specifically and digitisation of key documents is already under way. Onsite design offices will be set up on each site, and I note that the DIPDE has committed to provide the same level of support for the next VDs as it did for Tricastin and Bugey.

Some sites have seconded staff to Tricastin to support the site and to help themselves prepare for their own ten-yearly outages. This good practice needs to be replicated.

The electrical logic diagrams (see above) demand extra attention. The first-in-series teams and the DIPDE put a great deal of work into developing these diagrams, which is why we need to avoid needlessly repeating such efforts elsewhere. Each site will need to take full ownership of these diagrams so they can adapt them to meet their own site specifics and deal with any unforeseen issues.

Other than the modifications required, the most difficult tasks to complete were: reactor compliance checks; demonstration of the continued qualification of equipment beyond 40 years; compilation of regulatory documents; and document revisions. I urge the DPNT to learn from this experience when planning the next outages.

Departments at Tricastin made a concerted effort to achieve a more 'joined-up' approach in preparation for their ten-yearly outage. This is one of the most promising areas of progress in resolving some of the challenges facing the fleet, and I advise other sites to do the same wherever possible.

CONTROLLING THE LEVEL OF COMPLEXITY

So how will the situation look for the Operator coming out of these ten-yearly outages? The whole process will have felt much like sprinting a marathon; they will have been presented at the finish line with all the documentation for updating; control room operators will have been trained on all the implemented modifications; the reactors they will be restarting will be a somewhat different plant, with different physical characteristics and new standards.

The main modifications will have reinforced nuclear safety with enhanced defence in depth and have ensured compliance with the most recent standards. However, operability, which was not the focus of this review, will not have benefited from similar improvements.

Technical specifications, operating rules, maintenance routines, etc. will all have become more complex. A high level of support will be required to make sure these changes are taken on board fully.

Outage preparation activity at Tricastin nuclear power plant

Given that their primary aim was to demonstrate nuclear safety from a technical perspective, I am not convinced that adequate consideration has been given to the human and organisational factors (HOF) in the safety reviews. The focus on the formal aspect of accident studies meant that not all factors contributing to nuclear safety were taken into account. Greater emphasis should be placed on human and organisational factors, and particularly on the risk that all these changes bring with regards to their cumulative effect on system complexity.

TEN-YEARLY OUTAGES FOR THE 1300 MWE FLEET

VD3 outages are still ongoing in the 1300 MWe fleet whilst the fourth safety review is beginning. I am pleased to see that the most significant VD3 modifications, like the instrumentation and control system, are running smoothly, thanks to capitalising on scheduling and documentation from one outage to the next. The first VD4 outage is scheduled for 2026.

The Operator has submitted the safety review proposal (dossier d'orientation du réexamen, DOR) for the fourth review, which has been examined by the ASN. The initial idea was to base it on the VD4 900 outages, generally agreed to be comprehensive and robust. However, I see that requirements and demands are gradually increasing: the VD4 1300 outage workload looks to be even heavier than for the VD4 900 outages. I cannot stress enough how important it is not to lose focus, not to increase the complexity of the review, reactors and operations unduly, and to concentrate on the studies and modifications, which will bring about real improvements in nuclear safety.

It is true that the idea of these reviews is to consider the characteristics of new reactors (i.e. EPRs) and to identify any that could be integrated into existing reactors, nevertheless we should resist the temptation to simply align existing reactors with the EPRs wherever possible.

MY RECOMMENDATIONS

Fleet-wide standardisation, learning from OPEX and site support are all key to the success of the forthcoming VD4 900 outages. I recommend that the Director of the DPNT complete the project launched to address these issues.

For every VD4 900, I recommend that the Director of the DPN remain particularly vigilant during the work performed within the electrical facilities and main control room whilst at power to ensure that all the associated risks (reactor trips, fire, etc.) are controlled.

Safety reviews to date have focused on the technical aspects, which has led to numerous modifications. I recommend that the Directors of the DPNT and the DIPNN pay closer attention to the human and organisational factors in their study and modification programmes to mitigate the risk of excessive operational complexity.

Unit 1 containment ring lift - Hinkley Point C construction site

Several reactor projects are under way within the Group, laying the foundations for the future.

Design, fabrication and construction are the bedrock of high performance and nuclear safety.

The EDF staff and partner companies are key to this future, drawing on their expertise, experience and capability to integrate operating requirements into reactor design.

Significant efforts have been initiated to achieve excellence in the nuclear industry, project management and engineering methods.

The challenges ahead for new-builds beyond Flamanville 3 09

In addition to Flamanville 3 and the associated challenges I mentioned earlier (see My view) and in previous reports, other new-build projects of particular interest are the UK EPRs (Hinkley Point C and Sizewell C), EPR 2, and the NUWARD™ SMR[23].

THE MAIN EPR PROJECTS UNDER WAY

HINKLEY POINT C: PREPARING THE ELECTROMECHANICAL WORK

Construction work at Hinkley Point C was able to continue during the Covid-19 pandemic thanks to effective protective measures and the fact that most activities took place outside. The project was still able to hit major 2020 milestones, such as the final concrete pour to complete the Unit 2 raft at the end of May.

To meet the next challenge of installing the mechanical, electrical and HVAC (MEH) infrastructure, Area Directors have been appointed to schedule and coordinate activities in their area (nuclear island, turbine hall, etc.). The MEH Alliance of contractors responsible for installing the MEH equipment is rapidly gaining momentum.

The organisation is evolving, with the creation of some new structures:

- The UK EPR Design Centre in Bristol brings together engineers from the DIPNN, EDF Energy and partner organisations; it will help strengthen nuclear expertise in design, construction and commissioning in the UK, as well as help prepare operational support services.
- The Joint Design Office (JDO) is a site-based engineering team working closely with the UK Design Centre to provide a rapid response to problems encountered during construction.
- The Technical Client Organisation (TCO), located in Barnwood, will bring together Nuclear New Build (NNB) and EDF Energy Nuclear Generation resources to conduct design reviews for the new reactors (Hinkley Point C and Sizewell C) and provide technical support for in-service reactors (AGRs through to their dismantling, Sizewell B PWR, and subsequently EPRs).

SIZEWELL C: FIRST MILESTONES

Several key applications were submitted in 2020, including the Development Consent Order (DCO) in May and the Nuclear Site Licence (NSL) at the end of June. The Final Investment Decision (FID) is expected mid-2022. The commitment to replicate the design of Hinkley Point C is beneficial from a number of perspectives such as improved efficiency, budgeting, scheduling, quality and consequently nuclear safety.

Some necessary adaptations have already been identified based on differences in soil characteristics and coastal environment parameters such as: sand banks, flora and fauna, and tidal range. Others may still arise as the project progresses due to obsolescence or supplier-related issues, however, these should be kept to a minimum.

EPR 2: PREPARING THE TENDER DOCUMENTATION

The studies are progressing, with finalisation of the preliminary safety report and the tender documents before April 2021.

Some outstanding technical matters relating to aircraft impact and the requirements for the primary and secondary systems still need to be consolidated. Discussions with the ASN are ongoing.

From an industry standpoint, it is my view that a political decision to start a new series of nuclear reactors is critical to raise the profile of this technology, consolidate industrial capability and develop expertise, all of which are building blocks for improving quality.

EPRS: PROGRESS AND AREAS REQUIRING ATTENTION

The difficulties encountered at Flamanville 3, the start-up at Taishan and the start of construction at Hinkley Point C have all provided a great deal of operating experience (OPEX) in terms of design, organisation, know-how, Operator involvement and contractor relations.

KEEPING DESIGN CHANGES UNDER CONTROL

The safety assumptions and requirements for EPRs have evolved over the years, system by system, resulting in increasingly complex designs and operations. To complicate matters further, the initial intention to standardise equipment has not yet materialised.

The EPR 2 project aims to simplify the design, improve constructability and operating conditions, and reduce costs. It also incorporates OPEX from the other EPRs. This approach is highly conducive to improving safety.

[23] *Small modular reactor*

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EPR 2

This optimised version follows in the footsteps of the EPRs, but with the same nuclear safety features and main equipment.
Some EPR options have been reviewed, such as:

- A single reactor containment (with a liner) designed to resist external hazards
- Removal of the 'two-room' concept which allowed for maintenance in the reactor building while in service
- Reduction in the number of systems and equipment
- Redesign of the civil engineering structures
- Optimisation and enhancement of defence in depth, especially against extreme conditions (post-Fukushima).

The reactor performance, particularly its operational flexibility, has been adjusted to better work with a greener energy mix including a high fraction of renewables.

The EPR 2 design has standard 'off-the shelf' equipment wherever possible, and makes systematic use of standards, as promoted in the *plan excell* (*see My view*). This not only serves to standardise numerous items of equipment, but also offers advantages in terms of competitiveness, design, fabrication quality and maintenance.

Keeping a tight control over design changes is crucial and the initial progress made by integrating the PLM[24] tool within EPR 2 system engineering is encouraging. The traceability of all requirements allows the impact of a potential change to be identified before it is validated.

An excessive number of design changes has a detrimental effect on quality in any project, causing design complexity and disruption to studies, fabrication and construction. I therefore suggest that there is as much replication as possible between projects as intended with Sizewell C being based on Hinkley Point C, or EPR 2 having a series of identical reactor pairs.

STANDARDISING ENGINEERING METHODS AND TOOLS

The 'Process' and 'Product'[25] approaches introduced by the DIPNN both aim to improve and standardise practices, which have diverged over time between sites and projects.

The 46 processes identified cover all new-build activities from project structure and management to the handover to operations, including engineering, procurement, construction and commissioning. This is positive, but there is a danger that an overly detailed approach could make it difficult for the parties involved to take ownership.

The 'Product' approach aims to restore the level of standardisation that prevailed when the fleet's current reactor series were constructed. This has become more difficult with the EPR, with just a single unit in France and different licensing processes in other countries. 'Product owners' are gathering knowledge by bringing together numerous stakeholders: experts, Operators, R&D teams, designers, cost estimators, regulatory monitoring teams, suppliers, etc. They are providing ongoing support to teams working on tenders and new builds which should help to improve technical expertise overall. This approach should be extended to the in-service fleet.

These initiatives run in tandem with the digital transformation programme, Switch. Although these are all much needed changes, they have a considerable impact on managers and their teams, whose workload is already heavy. I urge everyone to remain pragmatic, not to get lost in the detail, and to consolidate methods and tools as soon as possible.

Sizewell C site layout model

I have also seen several local initiatives that have been set up to improve the reliability of studies. One such action is the preparation

[24] *Plant Lifecycle Management software*
[25] *A product is a functional or geographical part of a nuclear facility.*

of common detailed schedules, which must be agreed and followed by all parties involved. This is becoming a more widespread practice, however, I am concerned about the amount of work involved in updating all the 'level 4' schedules. The 'Error Reduction Tools' at Edvance are also a positive initiative.

Simulation tools help to improve the quality of studies by assisting the reactor operation validation process (control systems and operating procedures, etc.). I am pleased that the EPR 2 engineering simulator is now operational and offering extended functions.

SIMPLIFYING ORGANISATIONS AND STRENGTHENING PROJECT MANAGEMENT

Having the same functions conduct EPR project studies not only benefits operating experience, but also helps to build skills. I urge all entities involved, especially Edvance that has grown considerably, to adapt their organisation to achieve a simpler, clearer, more coherent set-up. It is also important to further develop a culture of personal accountability (*see Chapter 3*).

Concerning Hinkley Point C, site management has been outstanding since work began: the logistics and workflow management have been exemplary. On a more global level, several organisational decisions were taken in 2020 that are likely to have a positive impact on performance; these actions should be applied more widely, as planned at Sizewell C. However, organisation of the British EPR projects is still too complex; I urge that the number of interfaces be reduced and that cross-disciplinary decision-making be streamlined.

I have stressed the importance of independent oversight for engineering and new-build projects in previous reports. Actions underway in this direction must continue (*see Chapter 3*).

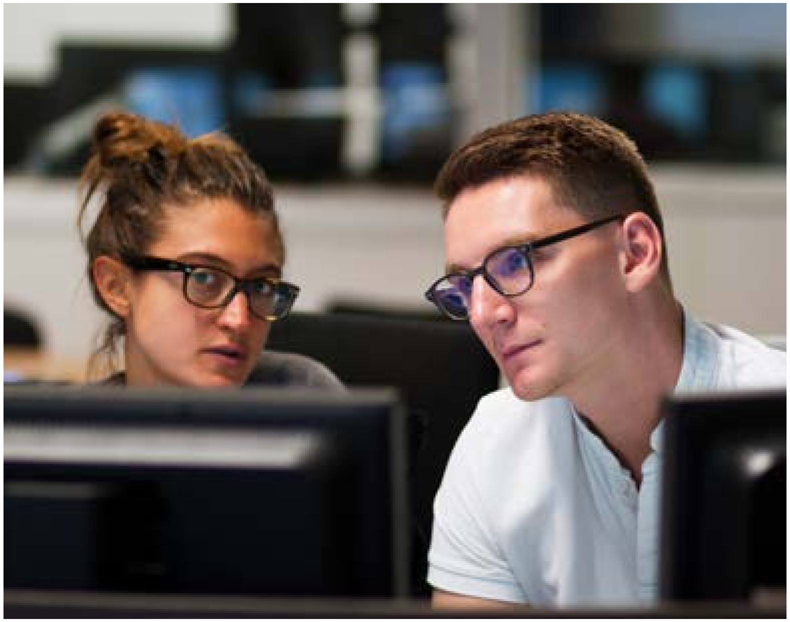
Tighter control of major projects is one of the main actions of the *plan excell* and I will be monitoring its impact on enhancing nuclear safety.

DEVELOPING KNOW-HOW IN TEAMS

During my visits, I met many motivated, enthusiastic people who are extremely committed to their work and keen to progress. However, their workload is increasing and new export projects could also be added to the mix. The pressure to improve productivity, although legitimate, should not lead to shortcuts being taken in terms of quality.

With this in mind, it is vital to develop engineering and project management expertise (*see Chapter 5*). A balance must also be found between the need to retain skills that are still essential for the Flamanville 3 project and transferring experienced staff to other projects.

A significant proportion of engineering work is contracted to partner companies. Outsourcing choices are often made in a rush to get through periods of peak activity. The type and volume of activities to be outsourced or performed in-house must be identified well in advance: carrying out targeted studies is an effective way of improving professionalism (*see Chapter 7*).



Engineers at Edvance

BOOSTING OPERATOR INVOLVEMENT

One of the key objectives for future reactors should be to improve operability. Involving the Operator from the design phase is essential to ensure learning from fleet operating experience. The Operator is not only part of the EPR 2 team, but also participates in its decision-making meetings. I appreciate the Operator's greater involvement in 2020 and the added momentum observed. I also take note of the considerable efforts engaged to guarantee the required level of operational flexibility. Going forward, I would like to see greater focus on certain subjects, such as fire, maintenance (specifically in-service maintenance), operations, plant alignment, tagging and spare parts. The DPN must make sure the necessary resources are available for the long term.

I also urge the UK Technical Client Organisation to take advantage of its role in supporting the fleet and new-build projects to optimise the operability of future EPRs.

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STRENGTHENING PARTNER RELATIONSHIPS WITH CONTRACTORS

Contractors play a key role in nuclear safety and quality. I have stressed the need for closer relations with partners in my previous reports; some progress has been made but more work is needed.

Alliance contracts bring together EDF Energy and its partners; already in place at Hinkley Point C, they allow for much closer collaboration and sharing the risks and benefits across all partners.

Involving the main suppliers before contracts are signed is also good practice. Early contractor involvement (ECI) helps partners come to a mutual understanding and allows them to anticipate the potential difficulties that might arise during construction, and how they might deal with them. This approach has already been implemented at Hinkley Point C and must be extended to the main EPR 2 contractors.

'Extended enterprise' work is evolving and showing promise. This approach aims to bring contractors together to share data and manage the interfaces between parties so as to harmonise practices. Involving contractors in the development of technical engineering standards also helps to ensure that the specifications correspond to best practices and innovative.

The Group's Procurement Division has simplified the general purchasing terms and conditions; it has done this based on its integrated approach to all contracts and operating experience from past projects. It is also setting up engineering contracts based on risk analysis conducted in conjunction with the engineering divisions. Calls for tender increasingly involve competitive dialogue or best offers. This encourages contractors to continuously improve in terms of expertise, management teams, number of temporary staff, and has a direct impact on the quality of their services.

Industrial policy would benefit from even closer alignment between the new builds, the existing fleet and decommissioning functions. There needs to be a more consolidated long-term vision of the Group's requirements to determine the best way to meet them and to give contractors greater visibility of EDF's expectations.

THE CHALLENGES OF NUWARD™

AN INNOVATIVE CONCEPT

There are now more than 70 SMR projects worldwide, twenty or so of which are pressurised water reactors. SMRs mark a turning point in reactor design, with a shift away from the usual objective of increasing their reactor power to improve their competitiveness. To offset the lack of scale effect, they rely on modularity, the series effect and simplification of design. They offer some extremely interesting safety features: their small size and low power aid cooling and increase autonomy in the event of loss of support systems.

France's wealth of experience in compact naval propulsion reactors means it has much to offer when it comes to designing SMRs.

The NUWARD™ SMR is considered complementary to high-power reactors like EPRs. With an optimum power output of 300-400 MWe, it offers an alternative to fossil fuel power stations in countries or regions that are either isolated or have an insufficiently robust power grid. It complements renewable energy sources and is suited for district heating. It also features many promising design concepts for nuclear safety, such as boron-free operation, a water wall surrounding the reactor containment, and the use of passive systems providing several days of autonomy in the event of degraded conditions such as the loss of off-site power sources.

NUWARD™ model

Studies began in France in 2010 and intensified during 2017 to 2019 with the completion of the feasibility study. The conceptual design has been entrusted to a project team of engineers from EDF, TechnicAtome, the CEA, and Naval Group, supported by their own in-house engineering teams.

Initial discussions have taken place with the ASN and IRSN. The project is now focusing on writing the safety options file (DOS) to authorise the product's licensing and thus its construction in France and potential deployment worldwide.

NUWARD™ design features

The NUWARD™ SMR is a Gen III+ pressurised water reactor in which the main components of the primary cooling system, the control rods, the compact steam generators, the pressuriser, and the canned motor primary pumps, are all installed in the reactor vessel. This vessel is then installed in a metal containment submerged in an underground water wall. It is designed for in-factory manufacture. The nuclear island is partially buried.
NUWARD™ features two independent reactor modules to provide a net power of 340 MWe. It is designed to operate in base load (constant power) and load following mode (variable power depending on grid requirements).

THE CHALLENGES AHEAD

Discussions about industrial arrangements and financing are ongoing. Defining the responsibilities and coordinating the expertise of each party involved will be key to the success of the project.

The technical innovations must be secured to ensure the feasibility of the project within the desired time frames. In particular, the compact plate-type steam generators, passive cooling systems and submerged control rod drive mechanisms are areas to be de-risked. A work programme has been set up for each topic: computer code adaptations, modelling and testing. I urge all project partners to mobilise the necessary resources and launch their test campaigns without delay.

MY RECOMMENDATIONS

Design changes often need to be incorporated throughout the course of a project. In order to manage this, I recommend that the directors of the DIPNN and EDF Energy continue their efforts in terms of:

- **Consolidating the design standards and replicating the design, from one project to the next, as much as possible**
- **Standardising equipment as per the *plan excell***
- **Harmonising engineering methods and tools as quickly as possible.**

Given the key role of contractors in quality and safety, I recommend that the directors of the DIPNN and EDF Energy seek the support of the Procurement Division in order to:

- **Place greater emphasis on industrial capability when choosing contractors**
- **Make contractors accountable for achieving the quality objectives**
- **Increase contractor involvement in the design and build phases.**

To date, work on reactor design has focused primarily on technical and economic performance, and nuclear safety. I recommend that the directors of the DIPNN and the DPNT work together to ensure that the new reactors also achieve a step change in operability.

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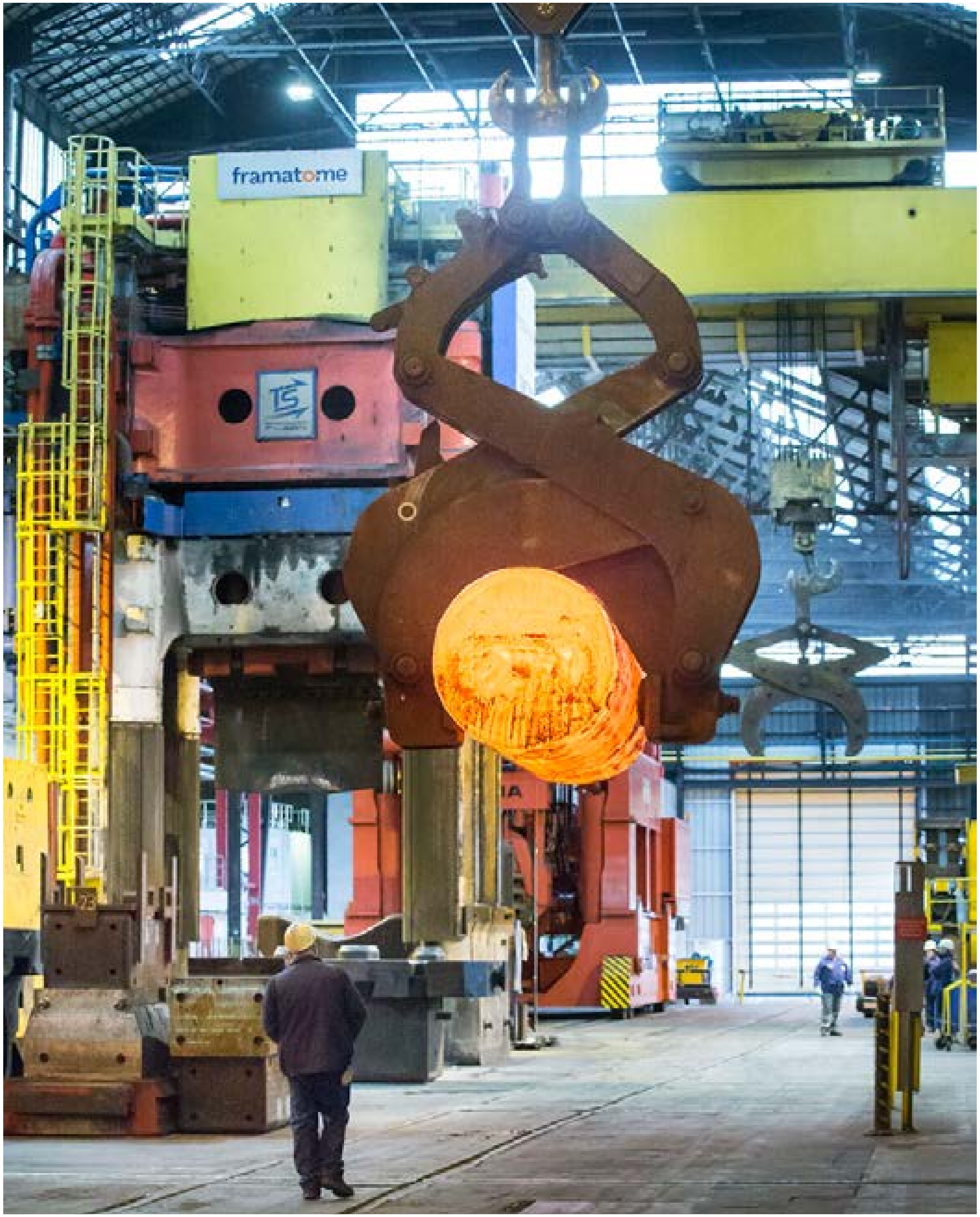

Forging an EPR component - Le Creusot fabrication plant

The quality of production - a strategic field at Framatome - is the focus of its 'Excell in Quality" plan, inspired by EDF's own *plan excell*. Quality is everyone's responsibility, from the business units (BU) through to the sub-contractors. This plan includes programmes for the industrial standardisation and stabilisation of tools used to manufacture large components.

By organising regular training sessions for everyone, Framatome has reiterated its intention to foster a nuclear safety culture that is shared by all its employees.

An independent nuclear safety oversight team is in place at the Romans-sur-Isère site and another is being set up within the Engineering and Technical Directorate (DTI). Its deployment in the other BUs calls for close consideration.

Report by the General Inspectorate of Framatome 10

Framatome supplies equipment and services to many sectors, both in France and abroad, i.e. nuclear fuel, engineering, major projects, reactor components, nuclear instrumentation, safety I&C, and nuclear facility maintenance. Most of these activities have a significant impact on nuclear safety.

This chapter has been written by Alain Payement, the Inspector General of Framatome, who shares his views based on his inspections. Owing to the highly specific role of the General Inspectorate, the structure and level of detail provided in this chapter differ from the others.

General Inspectorate of Framatome

The role of the General Inspectorate (IG) is to provide the Framatome CEO with an assessment of the robustness of nuclear safety in its operational units, both in France and overseas. The IG is headed by an Inspector General who is assisted by four inspectors (one more than in 2019).
The IG performs independent oversight of the organisation in the areas of nuclear safety, radiation protection, industrial safety[26], occupational safety, and the environment. Its activities are defined in a yearly programme which is presented to the Framatome executive committee.
During its inspections, the IG issues recommendations for the relevant business units to incorporate into their action plans. Progress is regularly checked by follow-up inspections.
The IG also conducts site visits to assess how nuclear safety and industrial safety are perceived by staff regardless of their managerial level and profession. Staff are interviewed without their managers during these visits. These visits help to detect weak signals.

NUCLEAR SAFETY CULTURE

Developing a nuclear safety culture is still a top priority. Framatome's nuclear safety culture relies on a three-tiered training plan: initial training for new employees within the first 6 months of their integration; specific training for managers joining the TOP 120; and periodic refresher training for everyone, as decided by the executive committee in 2020. The last tier is currently being deployed and addresses one of my recommendations from 2019.

To reach these objectives, a network of trainers has been deployed in each business unit. Owing to the pandemic, these training courses have been adapted to include modules that can be completed remotely. I would like to acknowledge the considerable resources that have been devoted to training.

These arrangements are supplemented by self-assessments of each site or division, which are carried out at least every four years using a tool developed by GIFEN[27].

The IG assessed the nuclear safety culture at the Jarrie site in 2020. Over a period of five days, the twelve members of the assessment team, including two managers from other BUs appointed by the executive committee, conducted close to 60 interviews and worksite visits. The key strengths identified were: strong managerial presence in the field, an esprit de corps, and good condition of work areas. The areas for improvement are similar to those identified during the assessment of other sites: applying standards, developing a questioning attitude, safeguarding know-how, and building a process that allows employees to voice their concerns without having to go through their hierarchy.

INDEPENDENT NUCLEAR SAFETY OVERSIGHT

The role of the independent nuclear safety oversight organisation is detailed in Framatome's nuclear safety policy. It ensures first-level oversight of the management hierarchy whose nuclear safety-related responsibilities have been reasserted for each site, business unit, directorate and corporate body. The IG undertakes the second level of oversight.

A specific internal document details the organisation and mission statement of this independent nuclear safety oversight body. I note that the existence of this document was not well-known. Other than the communication campaign led at all levels, the role

[26] *The management of industrial risks such as chemical hazards*
[27] *French nuclear industry association*

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of the independent nuclear safety oversight organisation must be incorporated into Framatome's organisational standards, such as the integrated management system manual. These changes should also help clarify the role of quality assurance in nuclear safety.

Other than the Romans-sur-Isère site that boasts a well-structured, operational independent oversight team keeping in line with its licensed nuclear facility classification, other business units are struggling to deploy their oversight arrangements, although progress has been made by the Engineering and Technical Directorate (DTI). Generally speaking, some members of the independent oversight organisation have not been formally appointed, the inspection programmes are few and far between, and yearly self-assessments are not always completed. I believe that proper deployment of the oversight organisations calls for a more binding schedule in 2021.

NUCLEAR SAFETY

NUCLEAR SAFETY MANAGEMENT

The determination to incorporate the safety requirements as early as possible into the analysis of all major quality non-conformities affecting Framatome's activities is a positive step forward. This task has recently been assigned to a committee chaired by the DTI's nuclear safety director. The nuclear safety and quality directors at Framatome, nuclear safety experts, the design authority, and representatives from the DTI's independent oversight team, all take part in these committee meetings. The Inspector General is usually a permanent member of this committee.

Its role is to analyse the consequences of non-conformities on nuclear safety and on compliance with regulations applicable in France (nuclear pressure equipment rules) or in the US (reporting of defects and non-compliance, 10 CFR part 21). Its assessment is formalised in a document and submitted to Framatome's quality director and its technical committee. This committee and its tasks are usually subject to review every year.

THE 'EXCELL IN QUALITY' PLAN

In 2020, Framatome initiated its 'Excell in Quality' plan - inspired by EDF's *plan excell* - that aims to achieve operational excellence in all business units. Both the objectives and significant means devoted to the Framatome plan reflect the intention to resolve the root causes of quality issues identified during the past few years. I believe the role of managers to be essential at every level when it comes to informing and encouraging employees at Framatome to adhere to the plan. I will be paying close attention to this point in 2021.

To further strengthen its industrial quality, Framatome has set up a division responsible for industrial standardisation and programmes; this covers aspects such as system engineering, product lifecycle management, and a new initiative called 'Juliette' to safeguard its manufacturing capability of large components for future nuclear programmes.

The tools behind the 'Excell in Quality' plan

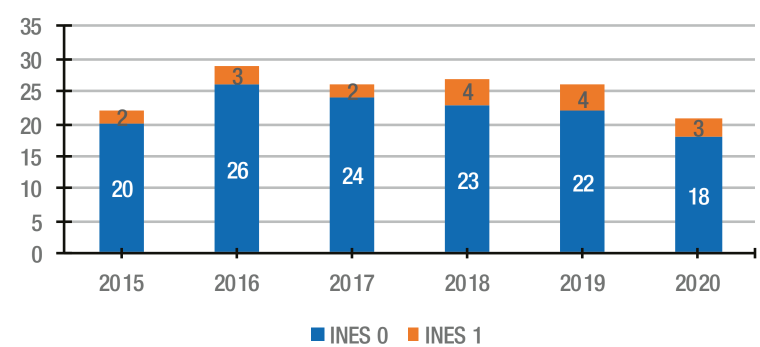
The 'Excell in Quality' plan focuses on six areas of progress designed to improve industrial quality profoundly:

- Encouraging commitment to quality: management practices and a culture of continuous improvement
- Ensuring the job is done properly the first time round: quality tools and operational excellence
- Using industrial processes efficiently: special processes, qualification methods, and digitalisation
- Fostering contractor involvement in quality activities: improved performance levels, improved and standardised performance assessment, strengthening of key qualification processes, and adjustment of inspection methods to integrate these changes
- Promoting excellence in key specialist skills: identification of critical skills, and centre of excellence in welding
- Relying further on support from the quality function: management of the 'Excell in Quality' plan, consolidation of quality inspection practices (Inspection Academy).

Regular updates are submitted to the Framatome executive board.

NUCLEAR SAFETY RESULTS

No INES Level 2 event or higher was declared in 2020. Furthermore, the number of significant nuclear safety events decreased compared with previous years: 18 Level 0 events and 3 Level 1 events, with 17 of these events occurring at the Romans-sur-Isère site (24 in 2019).



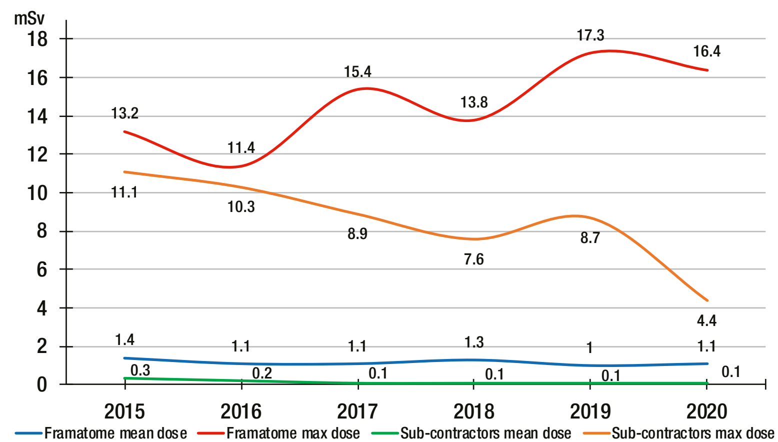
Variation in the number of INES events

This decrease, including in the total number of overall events (significant and relevant to safety), can be partially explained by the decrease in activities (excluding production) due to the pandemic. Some of the improvements are undoubtedly due to the various actions undertaken in 2020 to further improve: criticality risk management (including contractors), the use of human performance tools, and the overall nuclear safety culture. These encouraging trends are expected to be confirmed in 2021.

Analysis of these events has highlighted a more rigorous application of the rules, but it also shows that a careful and questioning attitude is still lacking in the majority of events. This observation confirms the need to continue the efforts with determination in order to strengthen the nuclear safety culture.

RADIATION PROTECTION

In 2020, the mean occupational doses for Framatome employees and contract partners were very similar to those recorded in 2019, reaching 1.05 millisievert (1.01 mSv in 2019) and 0.09 mSv (0.09 in 2019) respectively. The number of workers having received a dose below the minimum recordable level (zero dose) was 37% (38% in 2019) for Framatome and 23% (18% in 2019) for contract partners.

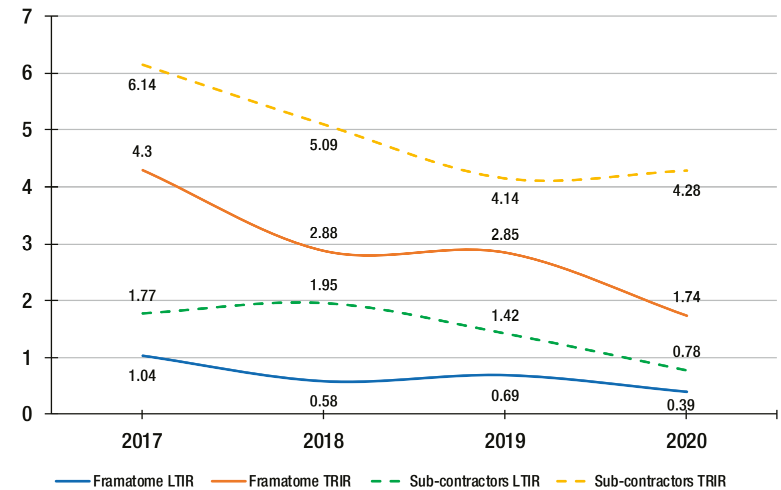


Variation in doses for Framatome and its contract parteners

This relative stability conceals the disparity between the doses received in the United States and France. In the US, activities were sustained with several important maintenance operations being completed, whereas in France the unit outage schedules were greatly affected by the pandemic. As a result, 53 of the 59 workers (26 in 2019) having received an annual dose exceeding 10 mSv were in the US. This was also the case for an employee having received the highest annual dose (16.4 mSv compared with 17.3 mSv in 2019), which is below the 20 mSv limit set by Framatome for all employees in the US[28]. Like last year, I would like to stress the importance of advance planning these occupational doses and the rigorous use of dose-related OPEX during reactor operations.

CONTINUOUS PROGRESS IN INDUSTRIAL SAFETY

The year 2020 was sadly marked by two fatalities due to road traffic accidents whilst commuting, one involving a Framatome employee and the other a sub-contractor.



Variation in accident frequency indicator rates

The 2020 objective to reduce the number of occupational accidents was achieved. The lost-time injury rate (LTIR) and the total recordable incident rate (TRIR) for Framatome staff were 0.39 and 1.74 respectively, which were better than their targets of 1 and 2.5. Further, both the LTIR and TRIR have dropped considerably compared with last year's results.

For contractors, this year's LTIR reached 0.78 which is much better than the target of 1.5, and their TRIR results are stable at 4.28.

Framatome's 'TOP 5 killers' programme came to an end in 2020 as planned; it set out to eliminate fatal risks associated with work at height, lifting operations, managing energy sources, using mobile

[28] *The regulatory limit in the US is 50 mSv/year*

equipment, and confined spaces. Amongst others, it helped improve compliance of equipment and standards. A corporate audit has been scheduled to assess how the practices in each BU compares with the best industry practices.

Once again, too many near-misses with potentially serious consequences occurred during handling operations (30% of event reports) despite the awareness campaign deployed in 2020. There must be a root cause analysis for every event of this type and subsequent sharing of the OPEX.

REVIEW OF INSPECTIONS AND VISITS

In 2020, the IG conducted 14 inspections on a specific subject, 11 follow-up inspections on the uptake of its recommendations, and 1 visit (Flamanville 3 EPR construction site). In light of the Covid-19 pandemic, two specific inspections were carried out remotely as their subject lent well to such conditions.

Inspection of a fuel plate at CERCA - Romans-sur-Isère

CHEMICAL SAFETY AND QUALIFICATION MANAGEMENT AT THE RICHLAND SITE

In the US, the IG carries out two inspections every year at the Richland fuel fabrication facility, as agreed with the US Nuclear Regulatory Commission (NRC). These inspections focus on a specific subject each time, either: emergency preparedness, radiation protection and the environment, fire safety, criticality management, chemical hazards, or staff education and training.

In 2020, the two inspections focused on chemical safety and the management of qualifications and training. In these two fields, the site has shown it has a rigorous organisation, robust processes, and qualified staff with good training. I encourage the Richland site management to incorporate the Framatome standards into its internal documentation. The actions defined following the audit on chemical safety need stronger guidance in their deployment. It should also be confirmed that the qualifications required of sub-contractors actually take into account all the risks associated with their activities.

FIRE SAFETY AT THE LINGEN AND ROMANS-SUR-ISÈRE SITES

The Lingen site in Germany and the Romans-sur-Isère site in France both benefit from detailed fire safety processes that are followed accordingly. The regulatory provisions are well-known and taken on board. The equipment and human resources devoted to fire-fighting are clearly identified and kept in good working condition. The Lingen site needs to focus more on fire prevention in the maintenance workshops. The Romans-sur-Isère site needs to systematically carry out risk assessments of its chemical products and consolidate the traceability of its regulatory training.

EMERGENCY RESPONSE MANAGEMENT AT THE ROMANS-SUR-ISÈRE SITE

The site boasts an organisation, processes, human resources and equipment capable of providing a swift response consistent with the emergency situation at hand. The response methods are regularly improved and tested.

Focus must be placed on: updating the onsite emergency plan, qualification of employees who manage the emergency response teams, and the periodic inspections and tests of safety-related equipment located in the emergency response headquarters.

OPERATIONAL RIGOUR

In 2020, inspections at the Ugine and Montreuil-Juigné sites focused on their compliance with the operational standards and the traceability of their activities. The nuclear safety, industrial safety and quality policies at these two sites are clearly defined and enforced through annual targets.

At the Ugine site, non-conformities are resolved efficiently and operating experience is exploited rigorously. The regulatory inspections and periodic tests could be more closely monitored.

The situation at the Montreuil-Juigné site requires particular attention. The number of changes at managerial level over the past year have weakened several key processes in industrial risk management: regulatory inspections and periodic tests, emergency response management, resolution of non-conformities, and plans designed to reduce industrial and environmental risks. In 2021, I will be closely monitoring the improvement actions launched by the new management team.

INCORPORATING SAFETY REQUIREMENTS INTO PRODUCTION

Four inspections on this new topic were carried out in 2020, focusing on the Saint-Marcel and le Creusot sites, the Hinkley Point C project team in Paris, and the Fuel Design Division in Lyon.

Generally speaking, the organisations, the distribution of responsibilities, the project management processes, and the resolution of non-conformities, have been adjusted to take into account nuclear safety requirements.

I would like to highlight the importance the sites have given to the management of critical skills and in consolidating the qualification of manufacturing processes. Further improvements must be made through better incorporation of OPEX, and in deploying an independent internal oversight structure.

The operational processes employed by the Hinkley Point C Paris project team must ensure that nuclear safety remains the overriding priority when faced with cost and time pressures.

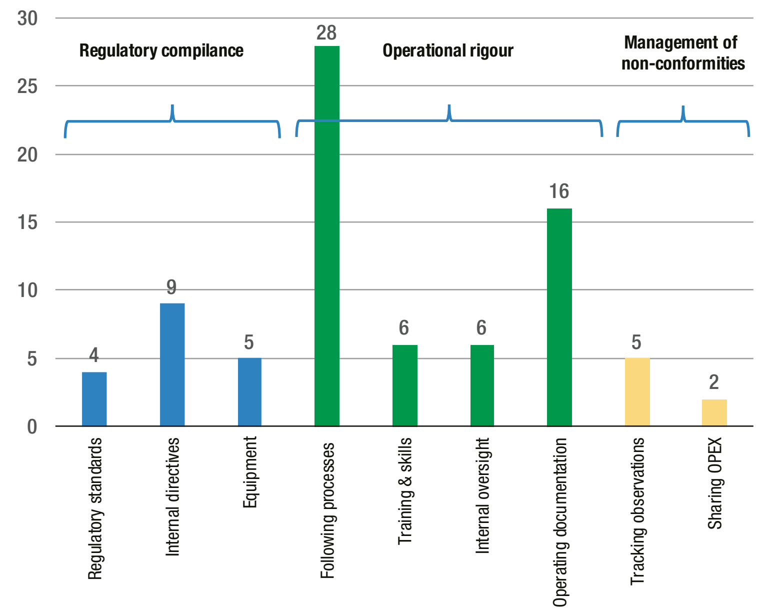
UPTAKE OF RECOMMENDATIONS

The number of recommendations in the process of being implemented improved this year, dropping to 81 compared with 94 in 2019. The IG issued 52 recommendations in 2020, compared with 37 in 2019. This positive outcome is the result of sustained efforts over the past two years to resolve the longest outstanding recommendations.

The number of recommendations dating back to more than two years has now been assigned an indicator, which is closely monitored by Framatome's executive committee. This indicator is also presented to the Framatome board of directors. In 2020, the target of less than 15 was successfully achieved. These efforts will continue in 2021 with a new target of 10.

The IG recommendations in progress in 2020 can be classified into three categories:

- Operational rigour (69%)
- Regulatory compliance (22%)
- Management of non-conformities (9%).



Recommendation categories (in progress)

As in previous years, operational rigour is the main subject of all recommendations mostly related to improvement or compliance with processes, and updating of operating documents.

MY RECOMMENDATIONS

The existence of a first level of independent nuclear safety oversight in all business units is a key pillar of Framatome's nuclear safety policy. To finalise its implementation in 2021, I recommend a more binding schedule and updating the organisational standards in order to better integrate the role of this independent oversight structure.

The number of industrial safety near-misses during lifting operations, with potentially serious consequences, has remained high for several years. I recommend that each event be systematically analysed to determine the root causes and the resulting OPEX be shared with all stakeholders.

The Flamanville site

APPENDICES

RESULTS FOR THE EDF SA FLEET

Nº	Indicators	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	0.91	1.55	1.19	1.14	1.16	0.98	1.12	1.28	1.45	1.4
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	10.57	11.90	11.60	10.8	10.03	9.78	11.59	12.6	12.7	12.4
3	Number of significant events per reactor • Non-compliance with technical specifications • Reactivity	1.36 -	1.52 -	1.34 -	1.55 -	1.24 -	1.48 -	1.41 0.9	1.69 0.7	1.8 0.9	1.5 0.6
4	Number of alignment errors[2] per reactor	2.07	1.78	1.22	1.41	1.74	1.64	1.78	1.24	1.4	1.3
5	Number of trips per reactor (for 7,000 hours of criticality[3]) • Automatic • Manual	0.50 0.05	0.55 0.03	0.59 0.03	0.53 0.07	0.66 0	0.48 0	0.38 0.04	0.31 0	0.53 0.03	0.29 0.04
6	Average operational collective dose per nuclear unit in service (in man-Sv)	0.71	0.67	0.79	0.72	0.71	0.76	0.61	0.67	0.74	0.61
7	Exposure of individuals: • Number of individuals with doses above 20 mSv • Number of individuals with doses between 16 and 20 mSv • Number of individuals with doses between 14 and 16 mSv	0 2 43	0 2 22	0 0 18	0 0 5	0 0 2	0 0 1	0 0 0	0 0 1	0 0 0	0 0 0
8	Number of significant radiation protection events	92	114	116	113	109	117	131	170	171	173
9	Availability (%)	80.7	79.7	78.0	80.9	80.8	79.6	77.1	76.5	74	71.9
10	Unplanned unavailability (%)	2.2	2.8	2.6	2.4	2.48	2.02	3.26	3.7	3.95	5
11	Occupational accident rate Tfg (per million hours worked)[4]	3.9	3.5	3.3	3.2	2.7	2.8	2.2	2.3	3.3	2.9
12	Occupational accident rate LTIR (per million hours worked)[4]	-	-	-	-	-	-	-	-	2.4	2.2

[1] *Excluding 'generic' events.*
[2] *Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event (statistical data reviewed in 2018).*
[3] *Average value for all reactors. unlike the WANO parameter which is based on the median value.*
[4] *Accident rate for EDF SA and its contractors*

RESULTS FOR THE EDF ENERGY FLEET

Nº	Indicators	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	1.33	0.80	0.80	0.33	0.47	0.27	0.47	0.53	0.27	0.07
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	4.70	4.60	5.13	4.47	7.40	10.00	6.13	5.93	6.73	5.47
3	Number of cases of non-compliance with technical specifications per reactor	0.33	1.67	0.67	1.53	1.00	0.80	0.60	0.60	0.67	0.87
4	Number of alignment errors[2] per reactor	0.33	3.07	3.33	2.80	2.87	3.13	0.93	1.67	1.67	1.00
5	Number of trips per reactor (per 7,000 hours of criticality[3])										
	• Automatic	0.74	0.64	0.45	1.17	0.57	0.3	0.49	0.89	0.56	0.35
	• Manual	1.22	0.84	1.03	0.62	0.19	0.42	0.37	0.20	0.32	0.00
6	Average operational collective dose per nuclear unit in service (in man-Sv)										
	• PWR	0.537	0.037	0.386	0.365	0.048	0.544	0.296	0.096	0.255	0.031
	• AGR	0.084	0.063	0.034	0.074	0.067	0.021	0.020	0.050	0.032	0.013
7	Number of individuals with doses above 15 mSv	0	0	0	0	0	0	0	0	0	0
8	Number of significant radiation protection events	43	50	27	27	18	20	10	23	28	26
9	Availability (%): • EDF Energy fleet	72.0	78.0	78.9	72.1	77.3	83.0	81.6	76.1	65.8	61.7
	• PWR	82.5	89.2	83.0	84.1	100	82.0	83.8	89.4	80.6	99.4
	• AGR	71.3	76.3	78.2	70.2	73.7	83.1	81.2	74.0	63.5	55.9
10	Unplanned unavailability (%): • EDF Energy fleet	13.0	8.9	6.9	10.7	2.3	5.1	5.0	3.1	4.0	5.0
	• PWR	3.4	9.9	0.2	0.7	0	0.1	0.0	2.2	0.2	0.6
	• AGR	13.7	8.7	7.9	12.3	2.7	5.8	5.7	3.3	4.7	6.2
11	Occupational accident rate LTIR (per million hours worked)[4]	0.6	0.5	0.2	0.2	0.4	0.3	0.2	0.5	0.3	0.3

[1] *Excluding 'generic' events (ones due to shortfalls in design)*
[2] *Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event*
[3] *Average value for all reactors, unlike the WANO parameter which is based on the median value*
[4] *Accident rate for EDF Nuclear Generation and its contractors*

Factors to be taken into account in comparing the results of EDF SA with those of EDF Energy:

- **Line 2:** the procedure for declaring events to the UK nuclear safety authority was **changed in 2015,** which means more events are now declared than in the past
- **Lines 3, 4 and 8:** the event declaration procedures are not the same in the United Kingdom and France because of the respective nuclear safety authority requirements. **EDF Energy and EDF SA harmonised their event classification practices in 2012.**
- **Line 6:** the reactors of the two different fleets do not share the same technology (mostly AGRs in the UK and PWRs in France). The AGR design means that radiation exposure is some 10 times lower (source: WANO).

KEY DATES FOR THE EDF SA NUCLEAR UNITS

Year in service	Nuclear unit	Power in MWe*	VD1	VD2	VD3	VD4
1977	Fessenheim 1	880	1989	1999	2009	N/A
1977	Fessenheim 2	880	1990	2000	2011	N/A
1978	Bugey 2	910	1989	2000	2010	2020
1978	Bugey 3	910	1991	2002	2013	-
1979	Bugey 4	880	1990	2001	2011	2020
1979	Bugey 5	880	1991	2001	2011	-
1980	Dampierre 1	890	1990	2000	2011	-
1980	Dampierre 2	890	1991	2002	2012	-
1980	Gravelines 1	910	1990	2001	2011	-
1980	Gravelines 2	910	1991	2002	2013	-
1980	Gravelines 3	910	1992	2001	2012	-
1980	Tricastin 1	915	1990	1998	2009	2019
1980	Tricastin 2	915	1991	2000	2011	-
1980	Tricastin 3	915	1992	2001	2012	-
1981	Blayais 1	910	1992	2002	2012	-
1981	Dampierre 3	890	1992	2003	2013	-
1981	Dampierre 4	890	1993	2004	2014	-
1981	Gravelines 4	910	1992	2003	2014	-
1981	St-Laurent B1	915	1995	2005	2015	-
1981	St-Laurent B2	915	1993	2003	2013	-
1981	Tricastin 4	915	1992	2004	2014	-
1982	Blayais 2	910	1993	2003	2013	-
1982	Chinon B1	905	1994	2003	2013	-
1983	Blayais 3	910	1994	2004	2015	-
1983	Blayais 4	910	1995	2005	2015	-
1983	Chinon B2	905	1996	2006	2016	-
1983	Cruas 1	915	1995	2005	2015	-
1984	Cruas 2	915	1997	2007	2018	-
1984	Cruas 3	915	1994	2004	2014	-
1984	Cruas 4	915	1996	2006	2016	-
1984	Gravelines 5	910	1996	2006	2016	-
1984	Paluel 1	1330	1996	2006	2016	-
1984	Paluel 2	1330	1995	2005	2018	-
1985	Flamanville 1	1330	1997	2008	2018	-
1985	Gravelines 6	910	1997	2007	2018	-
1985	Paluel 3	1330	1997	2007	2017	-
1985	St-Alban 1	1335	1997	2007	2017	-
1986	Cattenom 1	1300	1997	2006	2016	-
1986	Chinon B3	905	1999	2009	2019	-
1986	Flamanville 2	1330	1998	2008	2019	-
1986	Paluel 4	1330	1998	2008	2019	-
1986	St-Alban 2	1335	1998	2008	2018	-
1987	Belleville 1	1310	1999	2010	2020	-
1987	Cattenom 2	1300	1998	2008	2018	-
1987	Chinon B4	905	2000	2010	2020	-
1987	Nogent 1	1310	1998	2009	2019	-
1988	Belleville 2	1310	1999	2009	2019	-
1988	Nogent 2	1310	1999	2010	2020	-
1990	Cattenom 3	1300	2001	2011	-	-
1990	Golfech 1	1310	2001	2012	-	-
1990	Penly 1	1330	2002	2011	-	-
1991	Cattenom 4	1300	2003	2013	-	-
1992	Penly 2	1330	2004	2014	-	-
1993	Golfech 2	1310	2004	2014	-	-
1996	Chooz B1	1500	2010	2020	-	-
1997	Chooz B2	1500	2009	2019	-	-
1997	Civaux 1	1495	2011	-	-	-
1999	Civaux 2	1495	2012	-	-	-

VD1: First ten-yearly inspection outage
VD2: Second ten-yearly inspection outage
VD3: Third ten-yearly inspection outage
VD4: Fourth ten-yearly inspection outage

*Net continuous power

KEY DATES FOR THE EDF ENERGY NUCLEAR UNITS

Year in service	Nuclear unit	Reactor number	Power MWe RUP (1)	Planned date of withdrawal from service (2)
1976	Hinkley Point B	R3	480	2022
1976	Hinkley Point B	R4	475	2022
1976	Hunterston B	R3	480	2022
1976	Hunterston B	R4	485	2022
1983	Dungeness B	R21	525	2028
1983	Dungeness B	R22	525	2028
1983	Heysham 1	R1	580	2024
1983	Heysham 1	R2	575	2024
1983	Hartlepool	R1	595	2024
1983	Hartlepool	R2	585	2024
1988	Heysham 2	R7	615	2030
1988	Heysham 2	R8	615	2030
1988	Torness	R1	590	2030
1988	Torness	R2	595	2030
1995	Sizewell B		1198	2035

(1) Reference Unit Power (RUP):
the rated electrical power of the generating unit as declared by EDF Energy in its daily transactions at the end of 2014

(2) Dates of withdrawal from service include the final closure dates announced in 2020 for Hunterston B and Hinkley Point B.

EDF SA NUCLEAR SITES

Closed loop cooling

Open loop cooling

Pressurised Water Reactors (operation, construction and withdrawn from service)		
32	900 MWe	Operation
20	1 300 MWe	Operation
4	1 450 MWe	Operation
1	1 600 MWe (EPR)	Construction
2	900 MWe	Withdrawn from service

Engineering

8 Engineering centre

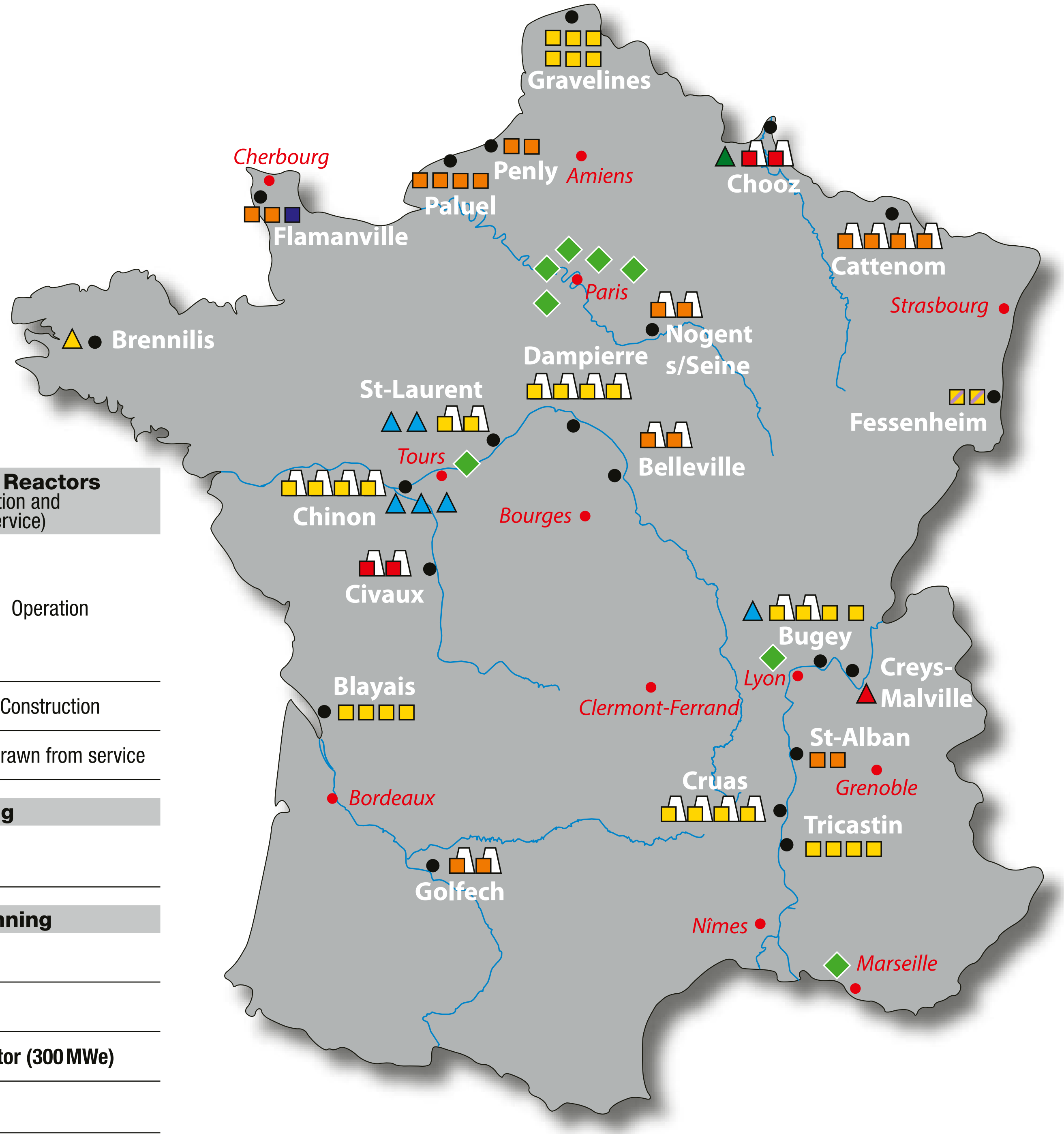
Decommissionning

6 Gas-Cooled Reactor

1 Heavy Water Reactor

1 Pressurised Water Reactor (300 MWe)

1 Fast Breeder Reactor



EDF ENERGY NUCLEAR SITES

FRAMATOME NUCLEAR SITES

TABLE OF ABBREVIATIONS

A

AFI	Areas for improvement
AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
AMT	EDF fleet maintenance agency
ANDRA	National Radioactive Waste Management Agency (F)
AREC	Reactive non-conformance analysis
ARENH	Regulated access to incumbent nuclear electricity, established in French law 2010
ASN	Nuclear Safety Authority (F)
ATEX	Explosive atmosphere

C

CCL	Local emergency response centre
CEA	Alternative Energies and Atomic Energy Commission (F)
CEFRI	Committee for the certification of companies in training and monitoring radiation workers (F)
CESC	Central Emergency Support Centre
CGN	China General Nuclear Power Corporation (China)
CNC	Civil Nuclear Constabulary (UK)
CNEPE	Electromechanical & plant engineering support department (DIPNN)
CNRS	National centre for scientific research (F)
COLIMO	A DPN campaign to modernise isolation and alignment practices and methods
COMSAT	Unit outage nuclear safety commission
COPAT	Unit outage operational control committee
CPO	Crew Performance Observation
CRT	Technical standards committee
CSN	Council for Nuclear Safety
CSNE	DPN nuclear safety review meeting

D

DACI	Independent oversight directorate for EDVANCE
DBUE	Deployable Back-Up Equipment (UK)
DCC	Core-fuel directorate
DCN	Nuclear fuel division
DFISQ	Independent nuclear safety and quality oversight department (DIPNN)
DI	Industrial division (DIPNN)
DIPDE	Nuclear fleet engineering, decommissioning & environment division
DIPNN	Engineering & new-build projects directorate
DOE	Department Of Energy (US)
DP2D	Decommissioning & waste directorate
DPN	Nuclear generation division
DPNT	Nuclear & conventional fleet directorate
DRS	Nuclear safety standards directorate
DSPTN	Project support and digital transformation department (DIPNN)
DT	Technical division at the DIPNN
DTEAM	Conventional fleet multi-disciplinary expertise & industrial support division
DTEO	Transformation and operational efficiency directorate
DTG	General technical division
DTI	Engineering and technical directorate (Framatome)

E

EATF	Enhanced Accident-Tolerant Fuel
EDT	Dedicated field team
EDVANCE	Joint venture between EDF and Framatome (80% and 20% respectively)
EGE	Overall nuclear safety assessment
EH	Emergency Handbook (UK)
EIPS	Equipment protected for nuclear safety reasons
EMAT	Shared teams providing support during unit outages
EIR	Rapid Maintenance Response Team (F)
EPR	European Pressurised Reactor
EPRI	Electric Power Research Institute (US)
ESPN	Nuclear pressure equipment
ESR	Significant radiation protection event
ESS	Significant nuclear safety event
EVEREST	EDF project to allow workers to enter controlled areas wearing ordinary work clothes

F

FARN	Nuclear rapid reaction force
FIN	Fix it Now Team (UK)
FIS	Independent nuclear safety oversight (F)
FME	Foreign Material Exclusion
FMECA	Failure Modes, Effects and Criticality Analysis
FSAT	Fire Safety Action Team (UK)

G

GDA	Generic Design Assessment (UK)
GECC	Core design and engineering group (UNIE)
GIFEN	Nuclear Industry Association (F)
GK	Fleet upgrade programme (F)
GPEC	Advanced planning of jobs and skills
GPSN	Nuclear safety performance group (UNIE)

H

HCTISN	High committee for transparency and information on nuclear matters (F)
HOF	Human and organisational factors
HPC	Hinkley Point C (UK)
HPT	Human Performance Tools

I

IAEA	International Atomic Energy Agency
ICPE	Environmentally regulated facility
ICRP	International Commission on Radiological Protection
IFOPSE	Fire Safety & Prevention Training Institute (F)
IN	Nuclear inspectorate (DPN)
INA	Independent Nuclear Assurance (EDF Energy)
INB	Licensed nuclear facility (F)
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operators (US)
INSAG	International Safety Advisory Group (IAEA)
IPCC	Intergovernmental panel on climate change (UN)
IRAS	Plant engineer assigned to relations with the ASN (NPPs)
IRSN	Institute for radiation protection and nuclear safety (F)

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J

JDO	Joint Design Office (UK)

L

LLS	Turbo-alternator last-resort power supply
LOCA	Loss-Of-Coolant Accident
LTIR	Lost-Time Injury Rate

M

MAAP	DPNT performance assessment and support team
MARN	Nuclear hazard management support team (F)
MEEI	Campaign for maintaining exemplary housekeeping (DPN initiative)
MEH	Mechanical, Electrical and HVAC (UK)
MLC	Onsite emergency response means
MME	Operations and maintenance methods
MQME	Campaign to raise the standards in maintenance and operation (DPN)

N

NCC	Operations core skills handbook (F)
N3C	Tagging and circuit configuration errors (F)
NCME	In-service maintenance core skills handbook (F)
NC STE	Non-compliance with technical specifications
NDA	Nuclear Decommissioning Authority (UK)
NEA	Nuclear Energy Agency (OECD)
NEI	Nuclear Energy Institute (US)
NNB	Nuclear New Build (EDF Energy)
NNSA	National Nuclear Safety Administration (China)
NPP	Nuclear Power Plant
NQME	Non-quality in maintenance and operations
NRC	Nuclear Regulatory Commission (US)

O

OIU	Internal inspection organisation
ONC	National emergency response organisation (F)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating experience
OSART	Operational Safety Review Team (IAEA)
OST	Task observation focused on skills and competences (F)

P

PBMP	Basic preventive maintenance programme
PCCF	Creusot forge compliance project
PCC-EO	DPN skill advisory centre for organisational effectiveness (F)
PCI	Pellet-cladding interactions
PDC	Nuclear engineering key skills development plan
PGAC	Worksite general assistance services
PIA	Protection-important activity (F)
PIC	Protection-important component (F)
PIRP	Industrial policy and contract partners relations team (DPN)
PLM	Plant Lifecycle Management
PPAS	Multi-year nuclear safety improvement plan (Framatome)
PPI	Off-site emergency response plan (F)
PSPG	Police site protection unit (F)
PUI	Onsite emergency plan (F)
PWR	Pressurised Water Reactor

R

R&D	Research & Development directorate
RGE	General operating rules (F)
RGV	Steam generator replacement
RIS	Emergency water injection system for reactor cooling
RTE	Power grid company (F)

S

SAT	Systematic Approach to Training
SBERG	Symptom-Based Emergency Response Guidelines
SDIN	Nuclear technical information system
SDIS	Local fire and rescue services (F)
SIR	Authorised internal inspection department
SMART	Digitalisation programme at the DIPDE
SMR	Small Modular Reactor
SOER	Significant Operating Experience Report issued by WANO
SOH	Socio-organizational and human approach
SP	Standardised plant teams (DPN)
SPR	Risk management department
SQEP	Suitably Qualified and Experienced Person
STE	Technical specifications
SWITCH	Digitalisation programme at the DIPNN
SYGMA	Computerised maintenance management system

T

TCO	Technical Client Organisation (UK)
Tfg	Occupational accident frequency factor (F)
TNPJVC	Joint venture between CGN (51%), Guangdong Yuedean Group Co. (19%) and EDF (30%)
TRIR	Total Recordable Injury Rate
TSM	Technical Support Mission by peers organised by WANO
TSN	Nuclear safety & transparency act (F)
TSSM	Technical Safety and Support Manager (UK)

U

UFPI	Operations & engineering training department (DTEAM)
UGM	EDF Group Management University
ULM	Maintenance & Logistics Unit (DTEAM)
UNGG	Gas-cooled graphite-moderated reactor (F)
UNIE	Operations engineering department (DPN)
UTO	Central technical support department (DPN)

V

VD	Ten-yearly inspection outage
VP	Partial inspection outage

W

WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association

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