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Current Challenges of the European Nuclear Supply Chain

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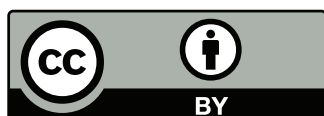
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Abstract

In 2018 the European Commission (its Directorates-General Joint Research Centre and Energy) as part of their activities on long-term operation (LTO) launched a project called "Modernisation and Optimisation of the European Nuclear Supply Chain" to investigate possible solutions for the supply chain challenges currently facing European utilities and licensees of nuclear facilities, in particular nuclear power plants (NPPs) for power generation, such as obsolescence of structures, systems and components (SSCs) and the difficulty in finding new suppliers for safety-related SSCs in nuclear facilities. This report is the first project deliverable and has the purpose to assess to what extent utilities in European countries with operating nuclear facilities are concerned about supply chain challenges and to what extent solutions to address these challenges in the sense of increased use of non-nuclear industry standard components and equipment for safety-related SSCs or use of SSCs designed and manufactured according to alternative nuclear codes and standards (other than the ones normally used in the country in scope) are already possible. The content of this report is based on information from two meetings the European Commission – Joint Research Centre organised with European utilities and national nuclear industry associations and from answers to a questionnaire provided by those organisations. Representatives of utilities or national nuclear industry associations from the following European countries attended the two meetings and kindly provided answers to the questionnaire and are thus covered by this report: Belgium, Czech Republic, Finland, France, Hungary, Romania, Slovenia, Spain, Sweden, Switzerland and the Ukraine (answers for the United States of America were provided as well for comparison).

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Executive summary

Context and motivation

In 2018 the European Commission (EC), Directorates-General Joint Research Centre (JRC) and Energy (ENER), as part of their activities on long-term operation (LTO) launched a project called "Modernisation and Optimisation of the European Nuclear Supply Chain" to investigate possible solutions for the supply chain challenges currently facing European utilities and licensees of nuclear facilities (in particular nuclear power plants (NPPs) for power generation) such as obsolescence of structures, systems and components (SSCs) and the difficulty in finding new suppliers for safety-related SSCs in nuclear facilities. The following routes are considered to provide adequate solutions to respond to these challenges:

1. Enable wide and general use of non-nuclear industry standard components and equipment (manufactured according to ISO, EN, etc.) in nuclear facilities, in particular for SSCs of lower safety class (SC3), without any additional nuclear specific requirements, providing (a) the components and equipment have a proven record of high quality and functionality, (b) they are subject to additional qualification tests to meet environmental and seismic requirements as appropriate and (c) they undergo a dedication process that provides reasonable assurance that they deliver their intended safety function.
2. Allow the use of safety-related SSCs produced according to alternative nuclear codes and standards, meaning nuclear codes and standards that are different to the ones that are normally used in the country that hosts the nuclear facility.

To assess the supply chain situation in European countries EC-JRC organised two meetings with representatives of European utilities and national nuclear industry associations plus European and international nuclear organisations and EC-ENER in June 2018 and March 2019 respectively. Beside presentation of the supply chain situation in their countries and associated challenges the representatives of the utilities or national nuclear industry associations were asked to answer a questionnaire. The latter contained nine questions addressing the following supply chain challenges: (i) level of concern about SSC obsolescence, (ii) difficulty to find new suppliers, (iii) & (iv) repair vs. replacement of safety-related SSCs, (v) procurement of "new" SSCs according to old legacy requirements, (vi) efforts and graded approach for quality assurance (QA) documentation for safety-related SSCs, (vii) use of non-nuclear industry standard components and equipment for safety-related SSCs, (viii) use of alternative nuclear codes and standards and (ix) use of modern state-of-the-art technologies for safety-related SSCs. Utilities or national nuclear industry associations of the following countries kindly answered the questionnaire (in alphabetical order): Belgium, Czech Republic, Finland, France, Hungary, Romania, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United States of America (U.S.)³

Main findings

The received answers showed that the utilities of the majority of European countries with NPPs in operation are significantly concerned about SSC obsolescence or it is becoming a growing concern while also having difficulties in finding new suppliers. "Elaborative" maintenance and repair of already installed SSCs is the preferred path forward for utilities in most European countries. Only if "elaborative" maintenance and repair is not possible anymore then replacement with modern similar SSCs is performed, which in most cases requires a lengthy and costly dedication and qualification process and final approval by the regulator. In some countries procurement of new safety-related SSCs to replace currently installed ones is performed according to old legacy requirements because the original requirements have not changed or to avoid qualification

³ Answers for the U.S. were kindly provided by the Electric Power Research Institute (EPRI) for comparison.

uncertainties and risks or because the current regulation does not support a different, modern and more efficient way forward.

In response to the above supply chain challenges the utilities in a number of European countries have implemented a commercial-grade dedication (CGD) process with the approval of their respective regulators. CGD is originally a process developed in the U.S. by EPRI for the U.S. nuclear industry and approved by U.S. Nuclear Regulatory Commission (U.S. NRC) to provide reasonable assurance that a component or piece of equipment produced according to a non-nuclear industry standard (commercial item) performs its intended safety function if used in safety-related SSCs of nuclear facilities. CGD allows utilities to procure non-nuclear industry standard components and equipment from suppliers that do not run a nuclear quality assurance (QA) programme and thus opens the door to new potential suppliers.

Utilities in Belgium, France and Switzerland performed CGD trials or have already performed CGD in the past. Utilities in the Czech Republic, Finland and Sweden are in the process of developing and implementing their own CGD processes to enable the use of modern high-quality non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities. The Romanian utility Nuclearelectrica and utilities in Spain have CGD processes already implemented and plan to use them more widely in the future in response to growing supply chain challenges. The utility of Slovenia, NEK, has a continuous investment programme in place, participates in joint and proactive supply chain initiatives (mainly U.S. based) and has had an established CGD process in place since 1995. As a consequence, NEK is less affected by supply chain issues than utilities in other European countries.

The use of alternative nuclear codes and standards for the design and manufacturing of safety-related SSCs is possible in the Czech Republic, Finland, Romania and the Ukraine after substantiation. In Belgium the usage of SSCs designed and manufactured according to alternative nuclear codes and standards is common practice and even included in the regulatory guidance. In France alternative nuclear codes and standards have been applied for a number of SC2 and SC3 SSCs for the European Pressurised Water Reactor currently under construction in Flamanville (Flammanville EPR™). In the remaining countries the use of alternative nuclear codes and standards is either not planned at the moment (Spain and Sweden), not allowed (Slovenia) or extremely challenging (Switzerland).

The use of modern state-of-the-art technologies for safety-related SSCs is only possible in the above countries if these technologies are either covered by nuclear codes and standards or they have been nuclear qualified via extensive tests to demonstrate their equivalence, robustness and safety function.

Key conclusions

The example of the Slovenian utility NEK shows that continuous investments (e.g. component replacements), participation in joint efforts with other utilities and an established CGD process is key in solving the supply chain challenges currently facing European nuclear utilities. If utilities of a European country decide to implement CGD then the approval of the respective national regulator is required, as national regulation most likely may need to be changed to allow the use of CGD. This means that a decision to move along this route has to be taken by all the nuclear stakeholders (utilities and regulator) in each country individually. If utilities of European countries decide to implement and perform CGD they should aim for wide cross-border collaboration including joint issuing of common and coherent documentation (e.g. technical specifications for SSCs) and data sharing from dedication processes and qualification tests of non-nuclear industry standard components and equipment. Ideally, European utilities shall perform CGD according to a common harmonised European approach or guidelines. Such an approach or guidelines need to be developed by European utilities in close interaction with European regulators based on international and European experience and accounting for European specifics. Developing such an approach or

guidelines requires review of supply chain management practices, technical requirements (design, manufacturing) and quality management (QM) practices for safety-related SSCs as well as benchmarking of these against technical requirements and QM practices of non-nuclear industries.

As regards the use of alternative nuclear codes and standards Belgium could be seen as a forerunner and possibly a good example to other European countries. However, this needs to be further assessed and documented in order for other European countries to benefit and build on the Belgian nuclear industry practice.

The implementation of a CGD process allowing wide use of modern non-nuclear industry standard components and equipment for safety-related SSCs and possibly the use of safety-related SSCs produced according to alternative nuclear codes and standards should also become the common future best practice for new-build reactors and even for future advanced reactors (i.e. small modular reactors (SMRs) of any coolant and Gen IV reactors) considering the long design life of 60 years for most of these reactors, as the existence of original equipment manufacturers of safety-related SSCs for such long time periods cannot be guaranteed and obsolescence of certain SSCs can be expected after a couple of years of operation (e.g. for I&C equipment). Operating Gen III/III+ and IV reactors with an established CGD process in place from the start of the new build project would mitigate running into the same supply chain challenges / legacy problems now facing the current European fleet.

It should be remembered that nuclear facilities are designed, constructed, operated and maintained for safe and reliable operation in accordance with high-level principles, requirements and concepts (e.g. Defence-in-Depth) and their safety may not be jeopardised by a single failure, human error or a combination of these. To ensure this, a nuclear facility design shall apply the concepts of diversity, redundancy, physical separation and functional independence throughout the lifetime of the facility. This requires the timely implementation of preventive and predictive maintenance of the nuclear facility by the use of modern SSCs of high quality and proven reliability, functioning when needed, from different and best available sources, including suppliers that offer and prefer producing SSCs according to non-nuclear industry standards or alternative nuclear codes and standards.

Related and future JRC work

EC-JRC continues to investigate the greater use of high-quality non-nuclear industry standard components and equipment in safety-related SSCs of nuclear facilities and greater use of SSCs according to alternative nuclear codes and standards to address supply chain challenges currently facing European utilities. In this sense EC-JRC intends to contribute to the review of supply chain management practices, technical requirements (design, manufacturing) and QM practices for safety-related SSCs and benchmarking these against technical requirements and QM practices of non-nuclear industries, as it does already within ongoing nuclear codes and standards development activities (e.g. CEN Workshop 64). EC-JRC intends to organise workshops with European regulators, technical safety organisations (TSOs) and utilities to inform and support them in this area, and already plans to organise a workshop on CGD primarily for European regulators and TSOs towards the end of 2020 together with EC-ENER. EC-JRC intends to contribute to planned European or international guidelines on CGD.

1 Motivation

1.1 Nuclear Supply Chain Challenges

Utilities are required to invest continuously in their nuclear facilities, in particular nuclear power plants (NPPs), to ensure the highest level of safety. Utilities are all mandated to comply with the World Association of Nuclear Operators (WANO) performance objectives and criteria (PO&C) [1]. The most relevant PO&C for this report are Equipment Performance (ER.1) and Equipment Failure Prevention (ER.2).

Equipment Performance (ER.1) obliges utilities to strive for high levels of reliability of equipment that supports nuclear safety, plant reliability and emergency response capability by (i) finding solutions to equipment problems in a thorough, timely manner with the support of engineering and other organisations (e.g. suppliers) and by (ii) identifying, prioritising and addressing long-standing equipment issues in a timely manner [1].

Equipment Failure Prevention (ER.2) obliges utilities to carry out preventive and predictive maintenance and performance monitoring to prevent failures of equipment important to safety, reliability and emergency response [1].

While complying with the WANO PO&C utilities are facing a number of increasing challenges related to the supply chain of safety-related structures, systems and components (SSCs).

The greatest challenge is **SSC obsolescence**. The original equipment manufacturers (OEMs) of the safety-related SSCs currently installed in nuclear facilities either do not exist anymore, have stopped producing the specific SSCs according to the original design as it is specified by the original equipment qualification (e.g. a requirement and justification for a like-for-like⁴ replacement of components and equipment of safety-related SSCs) or have discontinued nuclear quality assurance (QA) programmes required by the regulation.⁵

Equally challenging for utilities is **finding new SSC suppliers**. Potential new suppliers offer SSCs to utilities with an added risk-premium⁶ or chose not to sell to them at all, because:

- Potential new suppliers are not familiar with current legacy nuclear requirements (legacy nuclear industry standards) or do not understand them;
- Potential new suppliers are not interested in supplying to the nuclear industry / utilities because the market for such SSCs is too small; and
- Potential new suppliers consider the financial risk of supplying SSCs to the nuclear industry as too high.

Existing suppliers **lose interest to re-perform qualifications** even for SSCs supplied in the past, because the suppliers have adopted new modern best practice standards for their ongoing and normal production of SSCs to their non-nuclear industry customers.

⁴ U.S. NRC definition: "A like-for-like replacement is defined as the replacement of an item with an item that is identical. For example, the replacement item would be identical if it was purchased at the same time from the same vendor as the item it is replacing, or if the user can verify that there have been no changes in the design, materials, or manufacturing process since procurement of the item being replaced. If differences from the original item are identified in the replacement item, then the item is not identical, but similar to the item being replaced, and an evaluation is necessary to determine if any changes in design, material, or the manufacturing process could impact the functional characteristics and ultimately the component's ability to perform its required safety function." Link: <https://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/1991/gl91005.html>

⁵ SSC obsolescence is one of the reasons for the recent revision of WANO PO&C. Under reason for changes it states as point 12: "Increased emphasis on ageing and **obsolescence** issues in the equipment reliability area." [1]

⁶ According to European licensees the added risk-premium can be in the order of ten times the price of the same SSC if supplied in accordance with non-nuclear industry standards.

The cost of maintaining the skillset needed for production of SSCs in accordance with the legacy nuclear standards is no longer motivated due to the low order volumes and a perception of high financial risk driven by uncertainties.

The consequences of the above challenges are that utilities prefer to postpone heavy (and in some countries cumbersome) equipment qualification processes and avoid timely replacement of safety-related SSCs affected by obsolescence. Instead of replacing the affected SSCs, utilities may instead continue to repair and maintain the SSCs for as long as it is possible ("elaborative" maintenance), even though better similar state-of-the-art SSCs are in principle available (but not similar enough for a like-for-like replacement based on the old equipment qualification). Utilities may spend large efforts for procurement of "new" SSCs according to old legacy requirements in order to avoid equipment qualification uncertainties and risks. Often repair of currently installed SSCs is the preferred way forward in many countries with potentially considerable efforts for cost and personnel.

Beside the above challenges utilities are confronted with **formal strict QA documentation requirements** (methods & procedures predating ISO 9001) for safety-related SSCs. Utilities in some European countries perceive the efforts for issuing QA documentation for SSCs of lower safety class (SC), in particular for SC3, as excessively high and attribute this to "spill-over effects", meaning that more or less the same level of QA documentation for a SC3 SSC is required as for a SC1 or SC2 SSC, because it is to be used in a nuclear facility.

Utilities have the general difficulty to **receive approval for using modern state-of-the-art technology** for SSCs in nuclear facilities, because the national nuclear regulation does not allow it or the established nuclear design code or standard that is normally used in a country does not cover the modern state-of-the-art technologies or because of conservatism in practice.

Key to overcome the above supply chain challenges is to clarify (and possibly re-define) the link between nuclear safety requirements, as they are laid down in guidelines by WENRA, IAEA, etc., and the industry practice to manufacture, select and procure components and equipment for safety-related SSCs in nuclear facilities.

The above challenges originate from the time when the current fleet of NPPs were designed in the 1960s / 70s. In those days the existing industry standards used for design, manufacturing, quality control (QC) and QA of components and equipment were not sufficient for safety-related SSCs in nuclear facilities. Today's quality management (QM) standards according to the ISO 9000 family, which is the basis for QA of most non-nuclear industries, did not exist back then. This forced the nuclear industry to create their own nuclear specific codes and standards for safety-related SSCs to ensure the necessary quality and reliability of SSCs to perform their nuclear safety function. Components and equipment produced according to nuclear codes and standards ("nuclear-grade items") differed from similar items produced according to non-nuclear industry standards ("commercial-grade items") in terms of specifics related to the documentation of the applied manufacturing techniques and in their assembling, QA and QC requirements and corresponding documentation, inspections during production, performance testing and any other product life-cycle development steps.

These self-developed nuclear specific codes and standards became the established nuclear codes and standards as we know them today (e.g. ASME⁷, AFCEN⁸ codes, KTA⁹, etc.) and often they were (and still are in most cases) just developed at national level to satisfy the needs of the national nuclear industry. In addition, specific nuclear codes and standards became mandatory in national nuclear regulation in a significant number of countries, meaning for safety-related SSCs in nuclear facilities in a country only certain nuclear codes and standards may be used. Mixing of components and equipment

⁷ American Society of Mechanical Engineers

⁸ French Association for design, construction and in-service inspection rules for nuclear island components

⁹ "Kerntechnischer Ausschuss" (Nuclear Safety Standards Commission of Germany)

produced according to different nuclear codes and standards in the same nuclear facility is normally not best practice. As a result, the available supply chain for safety-related SSCs is artificially limited to those supplying components and equipment designed and produced according to one nuclear code and standard or the other. In addition to technical, material related, environmental related and other requirements nuclear codes and standards often define in detail the requirements for the management of QA and QC of the supplier. The evolving diversification of nuclear codes and standards across the various European countries with nuclear facilities since the 1960s / 70s has contributed and essentially led to the above supply chain challenges facing the nuclear industry today.

Non-nuclear industry standards (e.g. ISO, EN, ...) have progressed significantly in the last 30-40 years, including the QM standards of the ISO 9000 family that nowadays are the basis for QA of most non-nuclear industries. Since they were first introduced in 1987, they have become the most globally spread standards to ensure that products and services consistently meet customer's requirements and that their quality is consistently improved. This also applies to the nuclear sector in many countries, as national nuclear safety regulatory QA and QM requirements also refer to the standards within the ISO 9000 family.

Non-nuclear industry standards like the EN standards, as well as the ISO 9000 standard family, are continuously developed and frequently updated in order to improve the safety, quality and reliability of components and equipment. According to a recent study commissioned by Finnish utility TVO [2] the QA and QM requirements of safety-related SSCs in nuclear facilities in Finland are almost comparable with the corresponding requirements of the oil and gas industry for the same SSCs. High-quality – high-reliability SSCs can be produced by using well established non-nuclear industry standards like the American Petroleum Institute (API), International Electrotechnical Commission (IEC) and American National Standards Institute (ANSI) / International Society of Automation (ISA).

1.2 EC Project Modernisation & Optimisation of European Nuclear Supply Chain

As the above supply chain challenges are pressing issues for almost all utilities of NPPs in EU Member States and neighbouring countries, the European Commission (EC), Directorates-General Joint Research Centre (JRC) and Energy (ENER) launched a project called "Modernisation and Optimisation of the European Nuclear Supply Chain" in 2018 to investigate possible solutions for the above supply chain challenges along the following routes:

1. Enable wide and general use of non-nuclear industry standard components and equipment (manufactured according to ISO, EN, etc.) in nuclear facilities, in particular for SSCs of lower safety class (SC3), without any additional nuclear specific requirements, providing (a) the components and equipment have a proven record of high quality and functionality, (b) they are subject to additional qualification tests to meet environmental and seismic requirements as appropriate and (c) they undergo a dedication process that provides reasonable assurance that they deliver their intended safety function.
2. Allow the use of safety-related SSCs produced according to alternative nuclear codes and standards, meaning nuclear codes and standards that are different to the ones that are normally used in the country that hosts the nuclear facility.

Adoption of the first route would increase the pool of potential suppliers to those companies that are normally only active in non-nuclear industries. It would also give utilities and the nuclear industry in general the opportunity to benefit significantly from the massive progress in non-nuclear industry standards in the last 30-40 years (as briefly described in Section 1.1) by putting utilities in a position to procure modern high-quality

– high-reliability components and equipment produced according to these standards for safety-related SSCs in nuclear facilities.

Adoption of the second route would increase utilities' pool of suppliers to those companies that normally produce SSCs according to nuclear codes and standards different to the ones according to which the utilities' nuclear facilities were originally designed and constructed. As stated earlier mixing of components and equipment produced according to different nuclear codes and standards in the same nuclear facility is normally not best practice and should be performed with great care [3] [4]. In 2012 ASME Technologies LLC published a comprehensive study comparing well-established nuclear codes and standards for mechanical SC1 components [4]. The nuclear codes and standards that have been compared are French RCC-M, U.S. ASME (Section III), Canadian CSA (N-285), Japanese JSME (S NC1) and Korean KEA (KEPIC-MN). The study revealed differences in detail between the various nuclear codes and standards. The existence of these differences in detail does not mean that one nuclear code or standard is better than the others in the sense that its application results in better quality of mechanical components or an ability to provide an improved safety function. Differences in detail between the various nuclear codes and standards arise from the dependencies between the different requirements of the nuclear code or standard and the differences in detail are compensated by other requirements of the nuclear code or standard. The different nuclear codes and standards must be applied in their entirety to result in mechanical components with the intended quality. These conclusion have also been drawn by the nuclear regulators that participate in the Codes and Standards Working Group (CSWG) of the Multinational Design Evaluation Programme (MDEP) [3].

However, there could be cases where the use of SSCs according to alternative nuclear codes and standards is beneficial or even becomes necessary. The shutdown of KTA-based NPPs following the decision to phase-out nuclear power generation in Germany makes it economically unattractive for suppliers of such NPPs to upkeep their KTA certification and to still support utilities of the remaining KTA-based NPPs. This may force the utilities of the remaining KTA-based NPPs, e.g. in Switzerland, Spain and the Netherlands, to turn to suppliers offering SSCs according to alternative nuclear codes and standards (e.g. ASME) instead.

The use of an alternative nuclear code or standard may provide benefits, in the sense that it may cover a modern state-of-the-art technology that the nuclear codes and standards normally followed by a utility do not cover. For example, since its 2016 edition RCC-E¹⁰, the design and construction rules for electrical and instrumentation and control (I&C) systems and equipment of French type reactors, contains requirements and systematic approaches to qualify programmable digital electronic devices in I&C systems of nuclear facilities. These requirements and suggested approaches could be also of interest to utilities that normally do not follow AFCEN codes including RCC-E.

Besides increasing the pool of potential suppliers, the above two goals may also provide benefits for plant safety, because

- Installation of high-risk and high-cost first-of-a-kind (FoaK) designs would be largely avoided (FoaK SSCs is often the result of suppliers using tools (i.e. codes and standards) they are not familiar with);
- Suppliers would be allowed to use the standards and manufacturing methods they are most familiar with guaranteeing high SSC quality and functionality (this also enables a robust application of the suppliers SSC reliability data);
- The probability of common cause failures would be reduced due to the deployment of commonly used SSCs with a proven record of high quality and high

¹⁰ RCC-E are the design and construction rules for electrical and I&C systems and equipment of French type reactors. RCC-E is issued and maintained by AFCEN.

functionality from other industries and to use different designs for redundant systems more easily;

- Preventive and predictive maintenance and performance monitoring-based replacement / maintenance of SSCs would become easier, also allowing repair and re-use of replaced SSCs at another facility more easily; and
- Number of unplanned shutdowns are expected to be reduced as SSCs can be more easily replaced in a timely and predictable manner (which enables and enhances preventive and predictive maintenance).

The scope of the project is nuclear facilities such as the current reactor fleet, new-build reactors, radioactive waste management facilities and future advanced reactors (e.g. small modular reactors (SMRs), Gen IV).

1.3 Aim of this report

The use of non-nuclear industry standard components and equipment for safety-related SSCs or the use of safety-related SSCs produced according to alternative nuclear codes and standards in nuclear facilities is to some extent already common practice in a number of European countries or has been at least applied to some safety-related SSCs in a number of nuclear facilities in Europe on a trial basis within utility run pilot projects.

Utilities in a few European countries, most notably Slovenia, have a methodology in place for accepting components and equipment for safety-related SSCs in nuclear facilities that were designed and manufactured under a “commercial (non-nuclear industry)” QA programme. This methodology is commonly referred to as “commercial-grade dedication (CGD)”.

CGD was developed in the late 1980’s in response to increasing difficulties by utilities in the United States of America (U.S.), Slovenia and Spain to find nuclear qualified suppliers. Suppliers to the nuclear industry in these countries had (and still have) to have a stringent nuclear QA and QM system in place meeting the 18 requirements of U.S. regulation 10CFR50 Appendix B [5] and described in more detail the ASME NQA-1 standard [6]. CGD, as it has been implemented in the U.S. and a number of European countries is an acceptance method by which QA and QC becomes the responsibility of the utility rather than the supplier. In this way the utility can procure items or services from commercial (non-nuclear industry) suppliers that do not run and maintain a nuclear-specific QM system. This opened the door to more suppliers and procurement options for utilities in those countries compared to the restrictions on suppliers that conform to nuclear-specific QM systems. EPRI report no. 3002002982 [7] describes in detail the CGD process as it is applied in the U.S., Spain and Slovenia.

The purpose of this report is to assess the supply chain situation in European countries with operating NPPs and the extent to which the use of components and equipment manufactured according to non-nuclear industry standards (after going through a dedication process, either U.S.-based CGD or similar process) or alternative nuclear codes and standards for safety-related SSCs in nuclear facilities of those countries is already possible and under which conditions.

1.4 Methodology

To assess the supply chain situation in European countries EC-JRC organised two meetings with representatives of European utilities and/or national nuclear industry associations plus FORATOM, WANO, the World Nuclear Association (WNA) and EC-ENER in June 2018 and March 2019 respectively. Beside presentations of the supply chain situation in their countries and associated challenges the representatives of the utilities or national nuclear industry associations were asked to answer a questionnaire. The latter contained the following nine questions:

Question 1

To what extent is your company / are the utilities / licensees in your country concerned by SSC obsolescence issues? I.e. the Original Equipment Manufacturers (OEMs) of the safety-related SSCs currently installed in your nuclear facilities do not exist anymore or have stopped producing the specific SSCs according to the original design specifications (mandated by the original equipment qualification, e.g. a requirement and justification for a like-for-like replacement of the SSC in scope) and you envision that you will need to replace these SSCs within the foreseeable future?

Question 2

How difficult is it for your company / the utilities / licensees in your country to find suppliers for SSCs for your nuclear facilities? If it is difficult, what are the reasons? E.g. potential new suppliers of safety-related SSCs are not familiar with the current legacy nuclear requirements or do not understand them; potential new suppliers are not interested in supplying the nuclear industry / utilities because the market for such SSCs is too small; current legacy nuclear requirements are too difficult to comply with and the market is so small that the required effort does not justify the cost; potential suppliers consider the economic risk of supplying SSCs to the nuclear industry as too high; other difficulties?

Question 3

To what extent does your company / the utilities / licensees in your country avoid replacement of safety-related SSCs due to obsolescence issues, although better similar state-of-the-art SSCs are in principle available (but not similar enough for a like-for-like replacement based on the old qualification), but it is based on an unfamiliar nuclear or industrial standard resulting in a perceived uncertainty & risk in the qualification of the better state-of-the-art SSC that replacement is avoided and mending the currently installed SSCs is the preferred way forward?

Question 4

To what extent does your company / the utilities / licensees in your country spend large efforts mending (by elaborative maintenance measures) old SSCs instead of replacing them with new state-of-the-art ones? In this case it is envisioned that there are SSCs available in accordance with a known standard (nuclear or non-nuclear industrial) but replacement is still perceived as a risky way forward. This question is linked to the specific definition of what constitutes a like-for-like replacement of SSCs in your country.

Question 5

To what extent does your company / the utilities / licensees in your country spend large efforts in procuring "new" SSCs according to old legacy requirements in order to avoid qualification uncertainties and risks? (E.g. reverse engineering of SSCs according to old legacy requirements.) This question is also linked to the specific definition of what constitutes a like-for-like replacement of SSCs in your country.

Question 6

How does your company / the utilities / licensees in your country perceive the level of efforts required (high, moderate (as always) or small) for obtaining the desired quality assurance (QA) documentation for replacement / maintenance of safety-related SSCs for the current nuclear fleet and / or new build facilities? This in particular for SSCs of lower Safety Class (SC3)? If the level of efforts required are high what are the reasons (e.g. could it be regulation related "spill-over effects": Regulation in your country demands more or less the same level of QA documentation for a SC3 SSC as for SC1 / SC2 SSC, because it is to be used in a nuclear facility; is there uncertainty about the level of QA documentation needed resulting in a tendency of doing too much, e.g. more than is actually needed; conservatives in practice; industrial protectionism; a prevailing attitude of nuclear exceptionalism; other difficulties)?

Question 7

To what extent are non-nuclear industry standard components and equipment used or planned to be applied for safety-related SSCs in current nuclear facilities and / or new build nuclear facilities in your country? In particular, for SSCs of lower safety class (SC3 and lower)? If such components or equipment are difficult to use for safety-related SSCs, what are the obstacles against their use?

Question 8

To what extent are SSCs according to an alternative nuclear code or standard used or planned to be used in nuclear facilities in your country, current or new build? (Example: alternative nuclear code or standard could be nuclear design codes different to the one normally used in your country.) If not easily possible, what are the obstacles? (E.g. could it be unfamiliarity with the alternative nuclear code or standard by your national regulator, the independent reviewer (third party) or your own engineering staff? (Examples of alternative nuclear codes and standards: Russian PNAE G7, Korean KEPIC, Canadian CSA, Japanese JSME, French AFCEN and American ASME.)

Question 9

To what extent can you use modern state-of-the-art technology for safety-related SSCs in nuclear facilities in your country? If this is generally difficult what are the reasons (e.g. the national regulation does not allow it; the established nuclear design code or standard (normally used) does not cover the modern state-of-the-art technology (for example: 3D printing, powder metallurgy and high tech fibre composite components); conservatives in practise; other difficulties)?

Utilities or national nuclear industry associations of the following countries kindly sent answers to the questionnaire (in alphabetical order) and attended the above two meetings: Belgium, Czech Republic, Finland, France, Hungary, Romania, Slovenia, Spain, Sweden, Switzerland, Ukraine and the U.S.¹¹ Their answers are summarized in the following chapters.

¹¹ Answers for the U.S. were kindly provided by the Electric Power Research Institute (EPRI) for comparison.

2 Nuclear Supply Chain Situation in European Countries

2.1 Belgium

In Belgium SSC obsolescence starts to become an issue and consequently Electrabel and Tractebel (ENGIE) have established a dedicated team working on the topic, thereby exploring all possible options, from identifying new suppliers for affected SSCs to using new designs or new ways of manufacturing such SSCs.

The main difficulty is not to find suppliers that are able to produce nuclear-grade SSCs and are qualified accordingly, but to obtain high-quality SSCs from suppliers in general, irrespective whether they are nuclear-grade or not. Tractebel-ENGIE sees a decreasing will among suppliers to provide SSCs of acceptable quality. The main reasons for this trend are seen to be:

- Economic pressure resulting from delays caused by very ambitious delivery dates or toughly negotiated prices for SSCs;
- Lack of recognition (financially or in terms of provided training or support) of the importance of workers manufacturing the SSCs (e.g. welders, forgers, ...), whose impact on SSC quality is more significant than the QA system in place.

Replacement of obsolete SSCs with similar state-of-the-art SSCs (but not similar enough for a like-for-like replacement based on the old qualification) is mostly avoided in Belgium. Confidence in the reliability of SSCs (essential for safety-related SSCs) depends to a large extent on operating experience feedback. As the experience feedback for new technical solutions or SSCs that have never been used in a nuclear facility before is normally not available, their implementation in nuclear facilities is inevitably difficult. To compensate for the missing operating experience feedback a lot of qualification work is needed for new technical solutions of such SSCs. Because of the significant efforts for the qualification and fear not to succeed, ENGIE prefers not to go along this route.

In general, in Belgium ENGIE applies a policy of both maintaining / repairing already installed SSCs that have been in use for long time and replacing such SSCs with new state-of-the-art ones. The choice on which path to follow is based on an economic assessment considering timing, support by nuclear vendors, and safety impact. If the utility decides to replace a SSC with a new state-of-the-art one, normally an update of the original specifications and codes are made taking into account the evolution of the industry and the safety context.

ENGIE sees the effort by suppliers to issue QA documentation for SSCs as high, but this is needed for their safe and efficient operation. The utility has faced some difficult interventions on equipment, including justification of continued operation of some SSCs, because the original design and manufacturing files did not contain all the information to the required level. The reason for insufficient information is generally the reluctance of the supplier to provide all the required documentation of the SSC in scope, because of either the extra effort involved or reasons related to intellectual property.

ENGIE has experience in procuring and using components and equipment manufactured according to non-nuclear industry standards, i.e. commercial-grade items or various construction codes. This practice is not prohibited in Belgium and a corresponding methodology to accept commercial-grade items in nuclear facilities in Belgium has been developed. While for components and equipment manufactured according to accepted nuclear design codes and corresponding QA schemes performing its safety function is presumed to be guaranteed in all specified conditions, this needs to be demonstrated for commercial-grade items. This requires extra work, so that from an economic point of view there is no difference compared to using components and equipment manufactured according to accepted nuclear design codes or QA standards. Going the normal way of using components and equipment manufactured according to accepted nuclear design codes is easier than justifying an alternative. However, such an alternative may be

needed when supply of the SSC in scope according to the normal way is not possible within due time or when poor quality is expected from the usual nuclear supplier.

Procurement and installation of SSCs designed and manufactured according to other nuclear design codes than ASME Boiler and Pressure Vessel Code (BPVC, the reference nuclear design code in Belgium) is normal practice in Belgium. A code reconciliation is performed in those cases. This option was discussed with the nuclear regulator and was included in "regulatory" guidance documents¹².

If a specific equipment or piece of technology is covered by nuclear design codes it allows easy verification by the utility and the regulator that it is able to provide its safety function. Experience feedback is an important asset to demonstrate reliability of the equipment or piece of technology in scope.

Use of new technologies in nuclear facilities, especially if not yet codified, requires the utility to perform extensive studies to provide proof that the technology may be used for safety-related SSCs. Performing such studies jointly by several utilities, in particular for SSCs that are highly affected by obsolescence, helps achieving results at a reasonable cost. The results of these studies can then be used to build safety files complying with the local regulation.

2.2 Czech Republic

In the Czech Republic utility CEZ faces obsolescence problems for certain SSCs, because the OEMs terminated their production. SSCs that were only produced for nuclear facilities and which cannot be used in other non-nuclear plants pose the greatest challenge. In some cases the OEMs of these SSCs even no longer have the original design documentation that would allow in principle to re-produce the original SSCs. Also rapidly evolving technology for certain SSCs is another challenge, especially for instrumentation and control (I&C) systems. For this reason I&C systems have been replaced in Czech NPPs or will be replaced in the near future.

Finding new suppliers for SSCs in nuclear facilities in the Czech Republic is difficult. The market is too small and the costs for manufacturing SSCs meeting all the requirements associated with their usage in nuclear facilities is perceived as too high. As a result CEZ procures SSCs increasingly from foreign suppliers that are active in larger markets.

In general, maintenance and repair of already installed SSCs is the preferred path over replacement of SSCs due to obsolescence issues. SSCs are only replaced if maintenance has become impossible because of unavailability of spare parts or if it is more expensive than replacement with other similar SSCs. To use a similar safety-related SSC the national regulation mandates an approval process, even if the similar SSC is in accordance with a known standard. In the approval process the limitations given by the original design need to be respected (ensuring a like-for-like replacement).

Before the usage of any new type of SSC in nuclear facilities conformity with the project requirements of the nuclear facility and impacts of installing such a SSC is always assessed. As this requires quite some efforts like-for-like replacements of SSCs is preferred.

In the Czech Republic a graded approach for documentation of safety-related SSCs in nuclear facilities is applied, meaning that the scope of documentation for a SC3 SSC is lower than for a SC1 or SC2 SSC.

For SSCs of lower safety classes components and equipment designed and manufactured according to non-nuclear industry standards, standard commercial means (meeting the requirements of industrial standards) are used. To do so the component or equipment needs to meet defined quality requirements and testing needs to be performed to

¹² These documents are internal documents and thus not publicly available. A detailed description of the Belgian approach to the ASME BPVC, including potential alternatives, can be found in "Global Applications of ASME B&PV Code – Part 1", Chapter 5 "Belgium Pressure Equipment Regulation", published by ASME in 2016 [8].

demonstrate its safety function. The challenge of using such components and equipment is their timewise limited availability in the market. Thus for a possible replacement of the SSC in scope a few years later it is highly likely that the then available non-nuclear industry standard item needs to undergo testing to demonstrate its safety function again, if it does not allow for a like-to-like replacement.

The main factor for the decision whether a component or piece of equipment may be used for a safety-related SSC in a nuclear facility are its characteristics, that its quality has been proven and that it meets other requirements. Whether it complies with alternative nuclear codes and standards is only a supporting factor in the decision process.

Modern state-of-the-art technologies may only be used for safety-related SSCs in nuclear facilities after performance of extensive tests and analyses proving that their use will not reduce safety.

Due to the unavailability or limited availability of some SSCs in accordance with the current nuclear industry standards, CEZ is currently in intensive discussions with the regulator about the possibility and conditions of using commercial-grade items for SSCs of lower safety classes. A detailed proposal for a procedure to demonstrate the commercial items QA (CGD) has been developed. Pilot projects for selected SSCs (relay, thyristor, check-valve, opto-isolator) were implemented in accordance with the proposed procedure as a basis for the discussion with the regulator.

2.3 Finland

In Finland utilities are facing obsolescence issues. The number of suppliers of nuclear SSCs is lower than in the past and some OEMs do not exist anymore. Obsolescence is identified e.g. for analogue electronic items, control and protection systems (such as reactor protection systems), protection relays, frequency converters, ...

The number of suppliers for nuclear-grade SSCs seems to decrease further and the future outlook is not promising. For some nuclear-grade SSCs the number of potential suppliers is already very limited and the causes for this situation are the limited market and nuclear-specific requirements.

For many SSCs the available nuclear-grade components and equipment on the market are not the best ones or the ones of highest quality and sometimes not even the most reliable, but the ones that come with the most solid documentation. In particular among SSCs that nowadays contain programme code are cases where Finnish utilities made special arrangements instead of normal replacements.

To a large extent the lifetime of installed safety-related SSCs is extended by elaborative maintenance. Also old but still functional SSCs from decommissioned plants are used. The most challenging SSC to replace / modernise (and thus the one that poses most risks) is the automation system for which all possible alternatives are investigated. Replacement and modernisation is predominantly performed for non-safety SSCs.

Procuring new SSCs according to old legacy requirements is performed where applicable. However, for certain SSCs the requirements have changed since they were first approved thus not allowing this approach. For some SSCs arrangements were made to procure old SSCs and use them to replace the old and installed SSCs. One example is the replacement of the reactor automation system.

The level of efforts required for obtaining the needed QA documentation for replacement SSCs is seen as high, cumulating to several man-years annually in each involved company (utility and supplier). Even if there is certainty among the required level of documentation, the efforts for producing it is perceived as high, in particular for SC2 and SC3 SSCs. This has a direct impact on costs and supplier's willingness to provide offers and to supply SSCs.

Components and equipment designed, manufactured and documented according to non-nuclear industry standards are used for non-safety classified SSCs only. In principle they can be used for safety classified SSCs as well, especially for SC3 SSCs. Nevertheless, this path is normally not pursued, because it requires significant efforts and there is no commonly applied methodology for the dedication and qualification of such components and equipment. However, the Finnish utilities are in discussion with the regulator (STUK) in this matter and have launched a national project to change this (the KELPO project, see below).

In Finland the use of alternative nuclear codes and standards for safety-related SSCs is in principle possible, but requires dedicated approval of the regulator. This requires significant efforts by the utility to prove compliance of the proposed alternative codes and standards. Mutual recognition of regulator's acceptance of a SSC in one country by the regulator of another country would provide significant benefits.

The use of modern state-of-the-art technology for safety classified SSCs in nuclear facilities is extremely difficult. Modern state-of-the-art technologies normally do not have long operational histories, which hardly justifies the efforts for demonstrating their safety function to the regulator.

KELPO Project

The current supply chain challenges prompted the Finnish utilities Fortum, TVO and Fennovoima with support of the regulator STUK¹³ to launch a national project to ensure preconditions for the safe operation of the NPPs in the long term. As part of the project utilities develop procedures to qualify and license high-quality components and equipment produced according to non-nuclear industry standards for their usage in safety-related SSCs, especially of the lower safety classes. The objectives of this project, the KELPO project [9], are the following:

- Putting a graded approach into practice.
- Establish preconditions for the use of high-quality non-nuclear industry standard components and equipment for SC3 SSCs. In the first phase the focus is on mechanical components.
- Ensure a comprehensive vendor / supplier network.
- Suggest alternative methods for the development of qualification processes.

The KELPO project aims at ensuring and further developing nuclear safety and securing operating conditions of the nuclear industry in changing energy markets.

Phase 1 of the KELPO project was executed in 2018. The first action was to propose and possibly re-define roles of the involved organisations for supervising the manufacturing and QC & QA process of safety-related SSCs in nuclear facilities. While the regulator STUK will focus on plant level, system level and SC1 and SC2 SSCs the utilities will have an increased role for lower SC SSCs (especially SC3), as illustrated in Table 1.

The second action of Phase 1 was to propose ways to increase cooperation between the Finnish utilities with the aim of reducing overlapping work, utilising common approvals ("national approvals") and to define common and coherent documentation for safety-related SSCs and corresponding processes. The third action of Phase 1 was to propose a methodology to dedicate and qualify high-quality components and equipment according to well established non-nuclear industry standards for their use in safety-related SSCs of nuclear facilities. The targeted SSCs are SC2 and SC3 SSCs. With the methodology clear and predictable technical requirements for the components and equipment in scope for suppliers were issued, similar to other industries. The proposed methodology including

¹³ STUK adopted a new strategy: "Safety is not achieved through inspections but is a result of responsible operators safety solutions and human efforts."

the technical requirements are to be tested in Phase 2 and continued in Phase 3 of the KELPO project, which by the time of writing of this report are ongoing.

Table 1. Proposed new roles for regulatory approvals of plant-, system- and device level design and manufacturing oversight.

| | SC1 | SC2 | SC3 |
|---------------------|------|-----------------------------|------------------------|
| Plant level | STUK | STUK | STUK |
| System level | STUK | STUK / Utility | STUK / Utility |
| Device level | STUK | AIO ¹⁴ / Utility | Utility or third party |

The selected components and equipment for the pilot projects in Phase 2 and Phase 3 of the KELPO project are a valve (a mechanical component), a battery (an electrical device) and a product family of pressure transmitters (automation devices). The experience gained from Phases 2 and 3 will support and should finally result in a common methodology and corresponding documentation used by all Finnish utilities to dedicate and qualify high-quality components and equipment manufactured according to well established non-nuclear industry standards for their use in safety-related SSCs of nuclear facilities. This will enhance the licensing process of safety-related SSCs and, if needed, lead to proposals for changing the national regulatory framework.

Furthermore, the results and conclusions of the KELPO project should also contribute to more harmonised licensing practices (in the form of a licensing roadmap 2025) for safety-related SSCs in European nuclear facilities, for existing ones and for future advanced ones like SMRs. Throughout the KELPO project Finnish utilities closely interact with the EC supply chain project and similar national projects of other European countries like the one in Sweden (see below).

2.4 France

French utility EDF S.A. is running a large fleet of 56 units with an average age of more than 30 years. Consequently, EDF S.A. is very concerned about SSC obsolescence. Some suppliers have disappeared from the market while others have stopped producing the original SSCs. Nevertheless, the maintenance policy of the French fleet requires periodic replacement of some components and equipment. Modifications are defined and planned by the EDF S.A. engineering team to replace obsolete items with newer ones, subject to adaptation to the environment and the process in which the item in scope operates.

However, in the majority of cases, EDF S.A. has put in place contracts with original suppliers for maintaining equipment in operational conditions, repairing equipment or supplying new components. These contracts include provisions to preserve industrial capabilities, skills and tools, and to monitor evolutions in the manufacturing process that could affect the qualification performance of the equipment.

End-of-life stocks for certain items have also been created, in particular for electronic devices, which then benefit from specific storage conditions. Equipment replacement due to obsolescence is performed in a limited way for equipment qualified to accidental conditions (MQCA), with the support of the EDF S.A. engineering team.

¹⁴ Authorised inspection organisation (AIO). It is an organization that conducts tasks related to the conformity assessment and approval of the design and manufacturing of components and structures in nuclear facilities on behalf of the regulator, in this case STUK.

According to the EDF S.A. supplier panel there is a good level of response of potential suppliers for most of the SSCs of new-build projects involving the European Pressurised Water Reactor (EPR) allowing them to benefit from current EPR new-build projects in Finland, France, China and the UK. The nuclear codes and standards used for an EPR (the AFCEN codes) are the same ones as those required by the French nuclear regulation for the existing plants operated by EDF S.A. Although the number of suppliers for EDF S.A.'s fleet of reactors is showing a downward trend there is still a sufficient number of suppliers that are willing to follow AFCEN code requirements and thus ensure a good level of competition for all relevant SSCs. Moreover, as mentioned above, contracts with original suppliers allow maintaining sufficiently large business volumes for EDF S.A.'s main suppliers.

However, despite the large size of EDF S.A.'s reactor fleet and the number of EPR new-build projects, some companies decided not to supply the nuclear sector because of the necessary investments (qualification, documentation, QA) and the small volumes of components and equipment compared to other industries.

SSC obsolescence is subject to detailed studies within EDF S.A. Various solutions are investigated, including repair of installed SSCs, replacement with identical SSCs and replacement with similar SSCs requiring adaptation to the technical environment in which the SSCs in scope will operate and/or even additional equipment qualifications including corresponding reporting and documentation. EDF S.A. has the necessary engineering capacity and skills to accomplish these tasks, in particular if new equipment qualifications are required, taking benefit from EDF S.A.'s fleet size with a high level of commonly used SSCs.

Repeated manufacturing of small analogue electrical devices by specialised companies avoids obsolescence of these devices. Spare parts are normally provided according to the latest edition of the applicable codes & standards, so EDF S.A. does not need to procure SSCs according to old legacy requirements. If replacement of a SSC is needed EDF S.A. preferably aims for an identical replacement as much as possible.

The introduction of the nuclear pressure equipment decree (ESPN Decree) in France resulted in a significant increase in the amount of SSC documentation and thereby increasing the cost of safety-related SSCs. The requirements for SSC documentation according to the ESPN Decree are more stringent for SC1 SSCs compared to SC2 or SC3 SSCs indicating a graded approach.

For the qualification of components and equipment EDF S.A. takes benefit from reference files, which group together all the documents related to the manufacturing and/or repair of the SSC in scope, and keeps track of all modifications of the SSC in scope since it was manufactured and qualified. Generally, the level of documentation is substantial, even for non-safety SSCs, in view of needs for traceability, maintenance in the long-term and QA.

The use of non-nuclear industry standard components and equipment for safety-related SSCs is challenging, because such SSCs must meet the requirements of nuclear codes and standards for their design and manufacturing. Sizing methods, materials, manufacturing processes, QC and QA methods need to conform to the applicable nuclear codes and standards. Any non-compliances must be justified. Non-nuclear industry standards are normally far less prescriptive than nuclear codes and standards. Therefore, the application of a non-nuclear industry standard does not generally guarantee the compliance with nuclear codes and standards. In case components and equipment according to a non-nuclear industry standard (e.g. EN standard) are to be used for a safety-related SSC, EDF S.A. issues an additional specification to ensure the quality level required by the nuclear design code. Non-nuclear industry standard components and equipment are seldomly used for safety-related SSCs in NPPs operated by EDF S.A. If such components or equipment are used for safety-related SSCs comprehensive justification is needed and this could be provided according to EPRI guide no. 3002002982 [7].

EDF S.A. authorised the use of nuclear codes and standards other than AFCEN codes for safety-related SSCs in new build projects involving the EPR. For the EPR currently under construction in Flamanville, France, EDF S.A. accepts KTA and ASME BPVC for SC2 and SC3 mechanical SSCs, but the target quality level for these SSCs is the one according to RCC-M¹⁵. As a consequence, EDF SA has issued additional specifications to complement the requirements of the ASME BPVC code to obtain the quality level according to RCC-M.

EDF S.A. currently runs a project (the RTI project) on managing the engineering technical reference standards across EDF new build projects. It should lead to clarification and optimisation of requirements for new build projects, trying to distinguish as much as possible the requirements coming from non-nuclear industry standards and those specific to nuclear-classified items.

The use of modern state-of-the-art technology for safety classified SSCs in nuclear facilities is not prohibited in France and to some extent accounted for in the AFCEN codes. For example, the requirements for programmable digital electronic devices is included in RCC-E¹⁶ since the 2016 edition, which provides a framework for the use of such devices in EDF S.A.'s current fleet of reactors and EPR units under construction. This is very useful for instrumentation systems, but does not avoid the qualification of such devices. Qualification of programmable digital devices is a long process, in particular the qualification of their software.

2.5 Hungary

The OEMs of Paks NPP Units 1-4 or their post-Soviet successors disappeared from the market in the early 1990s and it was a significant challenge for its operator MVM-Paks to identify suitable suppliers for its SSCs, either successor companies of the OEMs or adequate new suppliers that were able to understand and deliver according to nuclear industry requirements. Fortunately, the OEMs built up quite considerable stock of spare parts before disappearing from the market and this made the supply of SSCs more plannable for MVM-Paks. In general suppliers of safety-related SSCs (meaning SC1, SC2 and SC3 SSCs) need to be adequately qualified in Hungary and require official authorization by the Hungarian Atomic Energy Authority (HAEA, the Hungarian nuclear regulator) to supply such SSCs.

The modernisation and replacement of obsolete components and equipment is an ongoing process. For the licensing process to extend the lifetime of Paks NPP Units 1-4 it was necessary to demonstrate and justify that the main SSCs operate safely until the end of the extended lifetime (and even beyond). MVM-Paks makes significant efforts to search and procure unutilised spare parts that were supplied by the OEMs to other companies.

Many potential suppliers are familiar with nuclear specific requirements, own the corresponding certificates (as mandated by the nuclear safety codes, etc.) and have references. But not all of them want to or can invest to establish an adequate QA and manufacturing system that meet the requirements and conditions of a nuclear industrial environment.

For most maintenance tasks MVM-Paks has an established network of suppliers and the relevant manufacturers or contractors have the required qualification. If a component or equipment is no longer available, the supplier offers an alternative solution for replacing the obsolete item. The replacement item needs to be re-licenced by the utility.

Another challenge is the public procurement process, which is felt as being very lengthy and complicated by potential new suppliers, who, as explained above, in addition need to undergo a qualification process to be eligible of supplying safety-related SSCs.

¹⁵ RCC-M are the design and construction rules for mechanical components of nuclear islands of French type PWRs. RCC-M is issued and maintained by AFCEN.

¹⁶ RCC-E are the design and construction rules for electrical and I&C systems and equipment of French type reactors. RCC-E is issued and maintained by AFCEN.

The policy of MVM-Paks is to use SSCs as long as they provide their function with a high level of reliability and without failures. This is based on MVM-Paks's experience that the overall effort for implementing new SSCs with state-of-the-art technology (in particular for qualification and licensing) is normally higher than for maintaining the installed SSCs. Thus replacement of installed SSCs with new ones is only considered if the replacement SSCs provide additional benefits in terms of lower operational and maintenance costs, higher electricity production and positive effect on plant safety. The primary concern here is the impact of the replacement SSCs on its system integration (e.g. extent of planned modifications, suitability for existing I&C systems). Thus if MVM-Paks decides to go along this route there must be positive and sufficient operational experience with the replacement SSCs from other utilities (good references). In cases where this experience is missing, thorough testing of the replacement SSCs and issuing of detailed technical justification is needed. Once a SSC has been successfully replaced with a new one the same solution is applied to all other units.

All SSCs must be procured, manufactured or installed in accordance with the requirements stipulated in the nuclear safety codes in force and the design base determined for each SSC. The qualification requirements for SSCs installed in Paks NPP were modified in the past (became more developed). However, each safety-related SSC to be installed in Paks NPP within a like-for-like replacement needs to be qualified beforehand. In conclusion, the procurement challenges and efforts for both cases, i.e. replacement of a SSC with a like-for-like SSC or with a SSC of exactly the same design than the currently installed one, are almost the same. However, like-for-like SSCs may provide higher reliance.

Components and equipment manufactured according to non-nuclear industry standards may be used for safety-related SSCs in nuclear facilities providing they meet the relevant requirements and the supplier is qualified.

State-of-the-art technologies may be used in nuclear facilities providing they are qualified and licensed and the supplier is licensed. However, certain technologies (e.g. pipelines made of high-density polyethylene or other plastics) are not allowed for safety-related SSCs.

For the new-build project Paks II the situation is slightly different and to some extent easier. The nuclear safety codes require that the selected suppliers hand over all the necessary design documentation for all SSCs to the utility. The design documentation provides an adequate basis to produce safety-related SSCs and using state-of-the-art components and equipment is a contractual obligation.

2.6 Romania

Nuclearelectrica, the operator of Cernavoda NPP in Romania, faces increasing challenges related to the supply of SSCs of its two CANDU 6 units at Cernavoda. Both units use SSCs dating back to the 1980s and the majority of their OEMs have left the nuclear market or have merged with other companies. As a result the knowledge associated with that technology has been lost or decreased by the companies that evolved from the OEMs due to strategic reasons. Due to the smaller knowledge base on the currently installed SSCs among the OEMs or their successor companies and advances in technology Nuclearelectrica expects to widely use new state-of-the-art technology SSCs to replace currently installed SSCs within the next ten years as part of plant refurbishment activities.

Finding new suppliers for its nuclear facilities is a challenge for Nuclearelectrica, because of the following reasons: (i) OEMs and traditional suppliers are no longer interested to supply the nuclear industry because of the associated risks, which do not outweigh the benefits; (ii) new potential suppliers are not interested to comply with nuclear requirements, perceive them as very expensive and not providing a sufficient long term perspective; (iii) some of the suppliers are big and powerful and try to impose their business conditions onto Nuclearelectrica in contracts; (iv) potential suppliers are not

familiar with the nuclear standards normally used in Romania; (v) countries / utilities with a small fleet of reactors is economically not attractive for potential suppliers.

Nuclearelectrica has a preventive maintenance programme for most SSCs in place and expands it regularly for SSCs with an increased risk of becoming defective. Nuclearelectrica spends significant efforts for maintenance and repair of installed SSCs, also because the alternative (replacement with a similar state-of-the-art SSC) is not always viable. The approach for an obsolete SSC, repair versus replacement with a similar state-of-the-art SSC, is chosen on a case-by-case basis, and depends upon a number of factors: (i) Potential supplier of a replacement SSC is not familiar with the requirements of the nuclear industry and perceives them as too demanding compared to the non-nuclear industry standards he is normally working with; (ii) SSC in scope is huge and expensive, which favours maintaining and repairing it rather than replacing it. If Nuclearelectrica chooses to repair a SSC instead of replacing it the reason is to avoid qualification uncertainties associated with the replacement SSC.

If replacement of an obsolete SSC becomes necessary, because maintenance and repair of the installed SSC is no longer possible, and a similar state-of-the-art SSC based on a non-nuclear industry standard is available, Nuclearelectrica performs a CGD process for the similar SSC with prior approval of the regulator. The CGD process gives reasonable assurance that the SSC will perform in such a way that the safety function is not affected. CGD is mandatory by law for components and equipment that are used for safety-related SSCs. Nuclearelectrica uses reverse engineering for those SSCs where the design documentation is missing and the OEMs do not exist anymore. This solution is the most costly and thus is used very cautiously.

Nuclearelectrica perceives the efforts for obtaining the necessary QA documentation for replacement / maintenance of SSCs in general as high. Traditional long-term suppliers usually provide all the required quality records, whereas the QA documentation provided by new suppliers is not always sufficient. Romanian regulation requires different types of documentation following a graded approach. The adequacy of required quality records and QA documentation is analysed on a case-by-case basis.

Depending upon the situation Nuclearelectrica may accept SSCs manufactured according to alternative nuclear codes and standards if equivalence with the Romanian legal requirements is proven and finally accepted by the regulator. Nuclearelectrica performs a GAP analysis between the legal requirements and the alternative nuclear code or standard. In call for tenders for the procurement of safety-related SSCs requirements of the nuclear standard normally used in Romania and mandated by law or an alternative nuclear code or standard (known by the supplier) and the gaps are included.

There is a high willingness of Nuclearelectrica to use modern state-of-the-art technologies more widely and their implementation is not seen as that difficult. As stated above the use of modern state-of-the-art technologies for safety-related SSCs requires a qualification process or CGD if qualification is not possible. While doing so it is strongly recommended to use proven technologies whose reliability has been previously demonstrated. The regulator encourages the use of modern state-of-the-art technology for safety-relevant SSCs, but does not encourage the use of novel technologies resulting in Foak designs.

2.7 Slovenia

NPP KRŠKO (NEK) has a continuous investment program (most of the major components have been replaced) thereby reducing the vulnerability to obsolescence. In parallel, a proactive approach exists through participating in joint industry efforts (e.g. Nuclear Utility Obsolescence Group (NUOG), International Nuclear Utility Obsolescence Group (INUOG), EPRI) and having membership in programs facilitating operators support for each other and access to existing solutions (Curtis-Wright / Scientech Rapidsmart). NEK also contracted Rolls-Royce's Proactive Obsolescence Management System (POMS) group

and Obsolescence manager service. All these efforts are encompassed and addressed in a plant programme and procedure.

Being an U.S. supplier turnkey project through Slovenian legislation, NEK complies with U.S. / U.S. NRC regulation and faces the same problems as U.S. utilities and the ones in Europe that follow the same regulation, codes and standards: disappearing suppliers, suppliers dropping nuclear production programmes, equipment / spare parts are not part of the current production programme and suppliers dropping production lines (obsolescence). At the same time NEK benefits from the joint efforts and already existing solutions.

Most of the safety-related SSCs of Krsko NPP were originally manufactured in the U.S. according to U.S. federal code 10CFR50 and U.S. codes and standards (ASME, IEEE, ANSI, ASTM,...) and also installed in other NPPs constructed at the same time (late 1970's / early 1980's in the U.S., Spain, Republic of Korea and Brazil). NEK faces two scenarios:

1. In case the OEM or his successor lost or dropped the 10CFR50 App B QA programme, there are companies providing third party qualification and NEK has developed a CGD process that can be applied in such cases.
2. In case the OEM has stopped manufacturing the SSC in scope or went out of business, there are companies that provide reverse-engineering services or have already existing solutions.

For both of the above scenarios, a surplus market can be addressed, meaning companies have bought surplus stock from operating NPPs, NPPs under construction and never completed or NPPs that were shut down or are in the process of being shut down. In cases where no direct or alternative replacement of the SSC in scope (equivalency evaluation) is available, a modification process is launched.

In case of good performance and spare parts availability, the obsolete SSC is kept and maintained. NEK complies with the laws, codes and standards as defined in the operating license, so no unfamiliar nuclear or non-nuclear industry standard is used. In cases where no "like-for-like" solution is available, the obsolescence issue is resolved through a modification process.

NEK has a yearly investment programme addressing improvements, replacements, licensing requirements, power and safety upgrades. A conservative philosophy is maintained and proven solutions are applied. Foak designs are avoided unless not otherwise possible. Like-for-like is addressed through the equivalency evaluation process.

In case of SSC replacements (maintenance), the original SSC design / technical specifications are used in conjunction with newer versions of codes and standards as allowed by code reconciliation and the licensing process. In case of SSC modifications, up to date codes and standards are applied.

The documentation requirements for SSCs are defined in the purchase order / contract and the documentation are either in the form of technical specifications (major components, new components) or technical and quality requirements (TQR, like-for-like replacements, spare parts). The requirements depend upon the safety classification, safety function and type of the SSC.

In general, documentation is delivered together with the procured item. In case witnessing of shop activities is required (e.g. factory acceptance test) NEK uses the opportunity to review and collect documentation.

Particular non-safety related SCCs that are important for plant operation or have specific requirements (e.g. fire protection) are classified as augmented quality (AQ). High-quality non-industry standards or specific standards (ISO 9000, Underwriters Laboratories) are applied and pertinent documentation is required.

The above is also systematically addressed during Nuclear Procurement Issues Council (NUPIC – U.S. utilities joint audits and approved suppliers list) audits, taking specific purchase orders as audit scope.

Non-nuclear industry components and equipment, intended for nuclear safety-related applications, are identified as such at the initiation of the procurement process. The nuclear grade qualification is obtained either by contracting a third party qualifier with a nuclear QA programme or through the process of CGD as defined in NEK programmes and procedures developed in accordance with the EPRI guidelines [7].

Alternative nuclear codes and standards to the U.S. codes and standards (ASME, IEEE, ANSI, etc.) are not used at Krško NPP. Slovenian legislation and NEK operating license (e.g. USAR) require compliance with U.S. nuclear regulation.

Concerning the use of modern state-of-the-art technologies the policy of Krško NPP is to look for proven solutions backed by corresponding references. In case the modern state-of-the-art technology is already nuclear qualified, it can be used. In general, they are used for non-safety related SSCs. A couple of years ago an obsolescence issue was resolved through reverse engineering and 3D printing. It was published and recognised as a best practice in the nuclear industry.

2.8 Spain

In Spain NPPs and utilities are facing increasing difficulties in replacing original SSCs and finding spare parts. Concerning the latter there is currently an on-going project on CGD in order to use non-nuclear industry standard components and equipment in safety related SSCs of NPPs. This concerns mainly electrical I&C equipment like relays and switches. According to the current nuclear regulation in Spain the use of non-nuclear industry standard components and equipment in nuclear facilities is only allowed when equivalent nuclear-grade components and equipment are not available in the market anymore. In general, CGD is allowed in Spain and supported by national regulatory guidance.

The number of suppliers of nuclear-grade SSCs has decreased over the years. Some OEMs do not exist anymore and many potential suppliers are not interested to supply to the nuclear industry / utilities due to the high efforts and investments required to adapt their products to nuclear requirements and due to the small potential market. The difficulty in finding new suppliers leads to the award of projects to a limited number of suppliers, typically the OEMs when still available, which results in high prices and not always receiving the highest competence.

Replacement of installed SSCs because of obsolescence is normally avoided providing the SSC in scope is still in a good condition. Replacement SSCs have to be manufactured according to the nuclear standards specified for the plant. As mentioned above the use of non-nuclear industry standard components and equipment in nuclear facilities is only allowed when equivalent nuclear-grade components and equipment are not available in the market anymore. If a non-nuclear industry standard component or equipment is installed within a safety-related SSC it has to undergo a CGD process beforehand. The purpose of this process is to demonstrate that the non-nuclear industry standard component or equipment has the same level of quality and reliability (and thus the same safety) than an equivalent nuclear-grade item. QA comprises all those planned and systematic actions necessary to provide adequate confidence that a SSC will perform satisfactorily in service, analysing the critical characteristics.

Procurement of SSCs is done in accordance with the original legacy requirements. Current regulation does not encourage utilities or nuclear industry to proceed in another way. The efforts for obtaining the desired QA documentation for replacement / maintenance SSCs is perceived as high and the level of detail as requested by the regulator is high. However, the amount of documentation required for a SC1 SSC is larger than for a SC3 SCC indicating a graded approach.

The use of alternative nuclear codes and standards for safety-related SSCs is not sought for NPPs in Spain. Use of modern state-of-the-art technologies for safety-related SSCs in NPPs is generally difficult and utilities would face the same challenges as for using non-nuclear industry standard components or equipment for safety-related SSCs.

2.9 Sweden

2.9.1 Vattenfall

Vattenfall has encountered quality problems and cost escalations in recent procurements of SSCs for its two pressurised water reactors (PWRs) at Ringhals and its three boiling water reactors (BWRs) at Forsmark. Also there is less interest from suppliers to bid in call for tenders for procurement of SSCs. For some obsolete SSCs the OEMs have low interest to support Vattenfall in the procurement process. I&C systems is an area of significant difficulty. The current strategy is to maintain as far as possible current I&C systems rather than to change them. This has resulted in re-manufacturing (and re-engineering) of original SSCs in some cases, which required rebuilding of separate assembly lines among suppliers.

European suppliers to the nuclear industry have disappeared or have changed the way they are manufacturing components and equipment, meaning that they have organised themselves according to today's common (non-nuclear) industry practice to specify and assemble SSCs and having multiple sub-suppliers themselves providing the detailed components. Thus suppliers that used to manufacture SSCs mostly alone now find themselves in between the nuclear industry and the world wide supply chain. New suppliers are not familiar with the legacy nuclear standards. The risk to deliver to the nuclear industry is unknown for potential new suppliers, which reduces their interest to bid in tenders from the nuclear industry. Long term relations with new suppliers are difficult to establish, because order volumes are low and difficult to predict.

For the re-manufacturing (re-engineering) of certain original SSCs state-of-the-art production methods or parts of them can sometimes not be used, because the replacement SSCs would then be considered as a design change which would in turn lead to a re-evaluation of the entire system in accordance with updated requirements (mandated by the Swedish regulation). The requirement in Sweden is that if the replacement of a SSC cannot be defined as a like-for-like replacement then the whole system needs to be re-evaluated against new updated modern requirements. Compliance to new regulations concerning earthquake, internal events, etc. are in many cases difficult to fulfil due to current design and layout of SSCs. This results in re-manufacturing (re-engineering) of original SSCs (e.g. relays, etc.) according to old (basically 1970s technology) requirements.

Maintenance of already installed SSCs in NPPs is the preferred choice and replacements are avoided where possible. For SSCs that need to be replaced, because elaborate maintenance measures do not allow their continued operation, new simplified "like-for-like" (1:1) replacement processes are introduced. These processes are to a large extent maintenance processes that contain replacements of components with new ones that come close to the original components. Simplified processes and safety reviews are performed.

Spending large efforts in procuring new SSCs according to old legacy requirements in order to avoid qualification uncertainties and risks is performed to some extent. The reactor protection system is a typical example. The original platforms are kept, because of the above reasons.

Vattenfall perceives the level of efforts required for obtaining the desired QA documentation for replacement SSCs for its NPPs as high compared to the benefits. Rather than accepting a certain set of QA certifications, specific QA-routines are performed for every supplier. This involves significant efforts for traveling and issuing of QA documents with only little or even no contribution to SSC end quality.

In general, the use of components and equipment produced according to non-nuclear industry standards for mechanical, pressure retaining SSCs of SC 1-3 in nuclear facilities is extremely challenging, as the use of such components and equipment requires extensive control documentation that is normally not provided by suppliers of commercial-grade items. However, Swedish utilities / licenses currently perform a joint project with the aim of implementing a CGD process enabling wider use of non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities (see Section 2.9.3). The CGD process will be according to EPRI report no. 3002002982 [7] and will involve a number of SSCs of different SC. Once the CGD process is implemented it will also be used by SKB to procure SSCs for its new back-end facilities.

SSCs manufactured according to alternative nuclear codes and standards have not been used in NPPs in Sweden yet and this option has not been fully assessed by Vattenfall yet, but the potential of this option is seen as high going forward.

Modern state-of-the-art technologies are not used in NPPs in Sweden. The problem is not the technology itself, but the requirements. If the form-fit-function is changed too much, the SSC in scope is subject to new updated requirements. The regulation requires that new updated requirements are imposed for all replacements not complying with the like-for-like (1:1) criteria.

2.9.2 Uniper

Uniper faces significant obsolescence challenges, especially for I&C systems. With regards to mechanical and process SSCs the competence and ability of the established suppliers is dwindling. For electrical SSCs and I&C systems there is growing reluctance among suppliers to support the nuclear industry. Also shifts in technology of such SSCs results in complicated rebuilding of plants.

There are in principal three methods to overcome SSC obsolescence: Repairing of installed SSCs, procurement of surplus equipment on the market and manufacturing of new SSCs according to old specifications.

The efforts for mending old SSCs is increasing, both in-house repair as well as collaborative campaigns. The efforts for procuring new SSCs according to old legacy requirements are still low at the moment, but there is an increasing trend.

The introduction of new suppliers into the supply chain is increasing the utility's effort to specify and control SSC quality and quality of SSC documentation. These efforts are more obvious than efforts of the utility to cope with changed requirements imposed by the regulator.

In Sweden there is a joint effort of all utilities and licensees aiming to increase the use of SSCs designed and manufactured according to non-nuclear industry standards. Swedish utilities and licensees are in discussion with the regulator in this matter (see next section). Usage of SSCs according to alternative nuclear codes and standards is of lower priority at the moment.

2.9.3 National Project "The Use of High-Quality Industrial-Grade Items" ("Industristandard")

In 2018 Swedish utilities and licensees published a position paper [10] stating that it should be possible to use non-nuclear industry standard components and equipment or alternative nuclear codes and standards for safety-related SSCs in nuclear facilities, for existing ones and new-build, after a suitable assessment (qualification + dedication) by the licensee. The appendix of the position paper provides additional guidance and justification for the position.

The publication of the position paper was followed by the launch of a pilot project by Swedish utilities and licensees with approval of the regulator SSM to use non-nuclear industry standard components and equipment (e.g. from oil & gas, marine, ...) for safety-

related SSCs in nuclear facilities and to implement a CGD process according to EPRI report no. 3002002982 [7]. In scope of the pilot project are a number of SSCs of different SC as shown in Table 2.

Crucial for the choice of SSCs in the pilot project was that they are components or pieces of equipment and not systems, which was a condition to receive support for the project by the regulator SSM. In the Swedish project there is a strict focus on components and pieces of equipment (and not systems). The aim is to have the CGD process for the SSC in Table 2 completed later in 2020. The Swedish utilities and licensees are willing to share data and experience on the CGD process with their counterparts in other countries.

Table 2. SSCs in scope of Swedish national project to implement an EPRI-type CGD process (yellow fields: primary areas for application of CGD).

| | SC1 | SC2 | SC3 | NNS |
|---|-----|-----|-----|-----|
| Sophisticated component (safety valve) | | | | |
| Subassembly (actuator) | | | | |
| Simple component (O-ring) | | | | |

2.10 Switzerland

Swiss utilities are facing SSC obsolescence issues for quite a while as part of their preventive maintenance strategy. Several OEMs have disappeared from the market in recent years, in particular as a result of the decision in Germany to phase out nuclear power generation. Procurement of spare parts is more challenging nowadays and replacement of existing SSCs requires additional resources than in the past. Some of the NPPs in Switzerland or certain SSCs in the plants are based on German KTA standards and hence may become challenging to replace.

The market situation for individual SSCs depends basically on the type of the component (mechanical, I&C, etc.). There are several reasons for potential suppliers not to supply to utilities and the nuclear sector (regulatory, political, economic etc.). Generally, the problem is related to the safety class and the construction, oversight and documentation requirements. The local market is small and fragmented, so additional efforts are needed to reach out to and attract potential suppliers.

Swiss NPPs follow a preventive maintenance strategy, which is based on rules set by the Swiss regulator and recommendations provided by the SSCs OEMs. The general approach is to identify obsolescence issues early enough before they can cause significant problems (e.g. availability, long lead time, etc.). However, with regards to ageing of the current fleet in the LTO perspective the situation is challenging, as obsolescence issues need to be addressed early enough as part of a long-term strategy, which is difficult due to the uncertain evolution of the nuclear industry. This trend may make SSC obsolescence more critical, as their timely replacement (if needed) may not be possible.

Following the Fukushima accident utilities strengthened the robustness of their plants against extreme accident scenarios. With this task now having been completed plant modernisation and SSC obsolescence is the main focus. Repairing installed SSCs or replacing them with more modern state-of-the-art technologies is decided on a case-by-case basis depending on the SSC type and on the specific situation. Furthermore, regulatory guidelines define which engineering design standards may be used for SSCs in

NPPs. If alternative solutions are introduced, a potentially lengthy justification and qualification process needs to be performed.

Generally, the procurement efforts of utilities for new SSCs depends on their type and on the specific situation. As long as original equipment can be purchased at a reasonable price, this is the preferred procurement route. Re-producing obsolete SSCs via reverse engineering can be a solution, especially for components that require a full assessment of economic and safety aspects. But normally reverse engineering is a timewise lengthy process and because of these factors reverse engineering of obsolete SSCs is rather unusual in Switzerland.

There are regulatory guidelines and utility specifications in Switzerland which define the rules and standards for QA documentation of SSCs in the nuclear industry (ASME, KTA, customer specific, etc.). Producing adequate QA documentation for SSCs depends on their type, safety class and the experience of the supplier. Introducing new equipment and devices for a SSC may lead to a potentially higher safety classification of the SSC in scope depending on its original SC and its function.

For SC3 SSCs use of non-nuclear industry standards is allowed if the original design of the SSC in scope is based on them. However, in 2019 the Swiss regulator has issued new guidelines and it will contain a new definition of the term "design" (in German "Auslegung") that will become part of the formal regulatory glossary. This new definition may impact the choice of SSCs in the future.

In Switzerland equipment in nuclear facilities is classified according to its importance for nuclear safety. A distinction is made between mechanical and electrical equipment as well as civil structures. The special requirements for SSC design, production, assembly and overall documentation are determined by the given safety classification. Third party testing and inspection during manufacturing and oversight by independent experts in the form of hold points accounts for a considerable proportion of the SSC costs.

For mechanical SC 1 and 2 SSCs only two nuclear design codes are allowed, German KTA standards and ASME Boiler and Pressure Vessel Code (BPVC), Section III, Division 1. For mechanical SC3 SSCs the use of an alternative nuclear code and standard is allowed, if the original design basis of the SSC in scope was already based on the alternative nuclear code and standard. The use of a nuclear code and standard other than KTA or ASME BPVC would most probably only be possible after compliance with nuclear design rules is demonstrated, gaps are justified and as long as this approach is not prohibited by nuclear ordinance.

2.11 Ukraine

Like all other operators of NPPs, Energoatom, the operator of all NPPs in the Ukraine, faces ageing of SSCs. Examples for active SSCs that were in scope of recent efforts for NPP lifetime extension are emergency diesel generators, polar cranes, valves, pumps, etc. Rehabilitation, modernisation and replacement of SSCs is subject to the requirements established in regulatory guide NP 306.2.106-2005 "Requirements to Nuclear Installation Modifications and Procedure for their Safety Assessment". It is based on IAEA safety guide NS-G-2.3 [11] and contains all the requirements for SSC modernisation, including SSC design development and testing.

The decision whether an obsolete SSC is replaced with an equivalent (like-for-like) or modified one as part of a modernisation or rehabilitation of the SSC in scope is taken on a case-by-case basis depending upon a number of factors, such as obsolescence, possibility and need to use modern state-of-the-art technology, efficiency etc.

Currently Energoatom does not experience any difficulties to find suppliers for SSCs installed in its NPPs. Instead it faces the opposite problem. Given that SE "NNEGC "Energoatom" is a state-owned company, all its procurements need to be carried out according to the procedures established in the Ukrainian law "On the Public

Procurements". This can lead to situations where bidders offer components and equipment that are not qualified for usage for safety-related SSCs in a NPP.

Energoatom does not experience significant technical issues with replacing SSCs with better similar state-of-the-art ones as such. The greatest challenges are the required efforts to achieve endorsement of the technical documentation by the regulator SNRIU and to prove the applicability of the normally advanced standard associated with the better similar state-of-the-art SSC.

Energoatom performs failure flow trend analysis for installed SSCs in NPPs and recommendations on maintenance practices are continuously made to improve the reliability of SSC functioning. Installed SSCs are used and maintained as long as economically feasible and safety is ensured. If a component or equipment needs to be replaced, because these conditions are not met anymore, Energoatom aims for replacement with an equivalent item. The definition of an equivalent item is given in regulatory guide NP 306.2.106-2005. An equivalent component or equipment is a component / equipment manufactured according to either the same technical specifications as the ones applied for the design of the nuclear facility or technical specifications that were approved earlier by the regulator for the same application.

Energoatom rarely procures components and equipment based on old legacy requirements, because for most SSCs it is impossible and impractical, in particular for I&C systems. As outlined above Energoatom aims for replacement with equivalent components and equipment whose definition is provided by regulatory guide NP 306.2.106-2005 and following the applicable codes and standards.

The level of efforts required for obtaining the desired QA for replacement / maintenance SSCs is generally perceived as high. The exact level of QA documentation for a replacement SSC is case specific and depends on the impact of the SSC replacement / modification on plant safety. Depending upon the case the required documentation package includes terms of reference, technical specification, design and operation documentation, QA programme, etc. Even for a SC3 SSC, as e.g. for most of the I&C systems and electrical equipment (some of them are SC2), a quite extensive documentation package is required as laid down in the NP and regulatory guidelines.

Non-nuclear industry standard components and equipment may be used in 4H systems (non-nuclear safety (NNS) systems) without any limitations. In some cases where such components and equipment are connected to safety-relevant SSCs or in case of special operational conditions, some level of care is needed. For SSCs of SC3 and higher the usage of non-nuclear industry standard components and equipment is subject to the applicable codes and standards for nuclear and radiation safety.

Energoatom has installed SSCs manufactured according to alternative nuclear codes and standards in its NPPs before and thus has significant experience in this. The challenge lies in the needed efforts for substantiation and receiving approval from the regulator.

Modern state-of-the-art technologies may be used for SSCs in nuclear facilities of Energoatom. The applicable codes and standards require that the robustness of such technologies is underlined via scientific research, experience from nuclear facilities of other countries and recommendations of international organisations. If modern state-of-the-art technologies are planned to be deployed for safety-related SSCs, testing of these technologies is mandatory in order to confirm required component / equipment characteristics and features. These tests are the main efforts for substantiation and to receive approval for their usage from the regulator.

2.12 United States of America

The paragraphs below summarise the answers to the questionnaire kindly provided by EPRI and are meant for comparison, to assess whether supply chain issues in the U.S. are similar to the ones of European utilities and what is possible in the U.S. to address these issues.

For U.S. utilities obsolescence is a primary concern as it increases lead time, costs and can result in additional engineering work preparing equivalency evaluations, design changes, etc.

Most U.S. suppliers have been established for quite some time and are extremely willing to meet customer needs. However, due to market conditions, some suppliers have decided to discontinue aging product lines or abandon their nuclear QA programmes. For the majority of such cases, this is due to low demand / revenue from nuclear product lines. For a few such cases, it is due to new leadership that either opposes nuclear energy or fears potential liability claims related to use of their products in nuclear facilities.

Generally it is difficult to attract new suppliers for the above reasons. In addition, potential new suppliers are not familiar with the current nuclear requirements or may not completely understand them. In addition, suppliers that provide safety-related items to commercial plants and several other types of nuclear facilities in the U.S. are subject to 10CFR21 "Reporting of Defects and Noncompliance" [12]. Compliance with 10CFR21 involves reporting defects and non-compliance associated with any safety-related item sold. The defect or non-compliance must be reported to all customers who purchased effected items as well as to the U.S. NRC. Furthermore, compliance with 10CFR21 entails providing access to the U.S. NRC for inspections. In addition, utilities (licensed to operate a commercial nuclear facility) in the U.S. must audit suppliers of safety related items / services at least once every 36 months. In addition to the cost and inconvenience associated with audits and inspections, suppliers have noted that the assessments are not always consistent and it seems like "requirements" and expectations change. In some cases, suppliers do not want to expose their quality programmes to the scrutiny of a nuclear audit, claiming that their "quality information" is proprietary.

In the context of U.S. regulations, any replacement used in a safety-related application must be established as equivalent (within the existing, approved design) or as a new or modified design that is established as suitable through a design change process. Engineering resources and cost considerations tend to encourage replacing SSCs and parts "in kind" rather than using newer technologies on a part or component basis. However, obsolescence "forces" evaluation of newer technologies. In addition, newer technologies such as digital controls are sometimes incorporated at the system-level. The U.S. NRC has demanding expectations with respect to use of new technologies and some regulatory requirements are fairly new as far as implementation is concerned. New technologies may be better in one respect, but could also introduce new failure modes and challenges in other respects.

Depending upon the specific situation "elaborate measures," such as reverse-engineering, are sometimes used. Many factors must be considered, and generally the more time that has elapsed since original design and procurement, the more challenge and potentially risk involved in making a change. A detailed process for reverse-engineering was recently developed in response to U.S. regulatory concerns with reverse-engineered items¹⁷. The process, developed with participation of U.S. NRC staff, is EPRI report no. 3002011678 [13].

The level of efforts required for obtaining the desired QA documentation for replacement / maintenance SSCs is perceived as moderate when using suppliers with recent

¹⁷ Information Notice 2016-09, Recent Issues Identified When Using Reverse Engineering Techniques in the Procurement of Safety-Related Components. U.S. Nuclear Regulatory Commission, Government Printing Office, Washington, D.C.: July 2016. ADAMS accession no. ML16075A285

experience. In general, augmented quality (non-safety-related items with some quality requirements) are well-understood and suppliers are either able to provide the required documentation or utilities are able to establish acceptability of the items. With regards to traditional safety classification¹⁸ ("safety-related", non-safety-related and "augmented quality") regulation applicable to commercial nuclear facilities in the U.S. does not demand the same level of quality.

Non-nuclear industry standard components and equipment (typically referred to as commercial, non-nuclear or commercial-grade in the U.S.) are generally used in non-safety-related applications for new-build if the items are not "first-of-a-kind" designs.

In the U.S. alternative (non-US) nuclear codes and standards are not used. All SSCs installed in nuclear facilities in the U.S. must comply with standards specified in U.S. regulations such as 10CFR50.55a [14].

Regulatory hurdles preclude widespread use of digital technology without extensive reviews and regulatory scrutiny, but an effort is underway to facilitate modernisation of instrumentation controls. Early efforts are underway to investigate use of replacement items manufactured using advanced methods such as additive manufacturing, powder metallurgy, etc. Standardisation organisations are also working to enable widespread use of these technologies.

¹⁸ Safety classification according to a risk-informed categorisation are typically not in use at U.S. plants although implementation is underway.

3 Summary

The answers from the utilities of the various EU member states, Switzerland and Ukraine mostly confirm the already identified challenges described in Section 1.1.

Questions 1 & 2: Level of concern about SSCs obsolescence issues and challenge to find new suppliers

The utilities of the European countries that have answered the questionnaire are either significantly concerned about SSC obsolescence, like the Czech Republic, Finland, France, Hungary, Spain, Sweden, Switzerland, or SSC obsolescence is becoming a growing concern, as in the case of Belgium, Romania and the Ukraine. Not surprisingly the utilities of the above countries, with the exception of France and the Ukraine, have significant difficulties in finding new suppliers. The utilities in France and the Ukraine, EDF S.A. and Energoatom, operate large fleets of standardized reactors that makes them economically attractive companies for potential suppliers to make business with. The Hungarian utility MVM-Paks has a large stock of spare parts and makes continuous efforts to spot them on the open market and other sources, which provides some relief from the challenge of finding new suppliers. Slovenian utility NEK has a continuous investment programme in place, is well embedded in joint industry programmes related to supply chain (e.g. NUOG, EPRI, ...) and has an established CGD process in place, reducing NEK's vulnerability to SSC obsolescence and making it to some extent easier to find new suppliers.

Questions 3 & 4: Repair vs. replacement of safety-related SSCs

The utilities of all the European countries in scope of this report mostly avoid replacement of safety-related SSCs with better similar state-of-the-art ones. "Elaborative" maintenance and repair of already installed SSCs is the preferred path forward. Only if "elaborative" maintenance and repair is not possible anymore then replacement with better similar SSCs is performed requiring in most cases a lengthy modification process involving qualification and approval by the regulator. The Slovenian utility NEK replaces obsolete SSCs either with a direct replacement upon safety screening and where no modification is necessary, or with an alternative SSC in which case a modification process needs to be applied. If a commercial-grade item is used a CGD process needs to be applied. The Swiss utilities take the decision of "elaborative" maintenance and repair vs. replacement of obsolete SSCs on a case-by-case basis. If replacement of an obsolete SSC is needed, it should be preferably replaced with the same one to avoid otherwise necessary qualification and approval processes. This is also the approach taken by utilities of virtually all other countries.

Question 5: Procurement of SSCs according to old legacy requirements

Procurement of safety-related SSCs according to old legacy requirements (meaning to reproduce currently installed SSCs in nuclear facilities via e.g. reverse engineering) for their replacement is common practice in Finland and Spain and pursued for SSCs where the original requirements have not changed or, as in the case of Spain, the current regulation does not support a different way. In Sweden utilities and licensees also procure SSCs according to old legacy requirements to some extent to avoid qualification uncertainties and risks associated with replacement with more modern SSCs. Nuclearelectrica in Romania performs reverse engineering for those SSCs where the original design documentation is missing and the OEMs do not exist anymore.

In all other countries procurement of SSCs in nuclear facilities is accomplished according to currently valid requirements or they are revised according to more modern state-of-the-art SSCs. In Belgium, if replacement of a SSC with a similar state-of-the-art one is considered the original specifications are updated accordingly and a reconciliation is performed. In Hungary all SSCs procured, manufactured and installed in nuclear facilities are according to the requirements stipulated in the national regulation in force and the design base determined for the SSC in scope. In Slovenia procurement of new SSCs requiring design modification is performed according to up-to-date codes and standards

and requirements. Procurement of like-for-like replacements of installed SSCs is performed to its original codes, standards and requirements. Energoatom in Ukraine procures SSCs according to the current codes and standards and requirements. Procuring SSCs according to old legacy requirements is seen as impractical by Energoatom.

Question 6: Efforts and graded approach for QA documentation

With regards to the needed efforts for issuing QA documentation for replacement SSCs, there is a graded approach in place in most of the countries, in the sense that the level of required QA documentation is related to the SC of the SSC in scope, meaning that the amount of QA documentation for a SC3 SSC is lower than for a SC1 SSC. In the Czech Republic, Romania and Spain the efforts for issuing QA documentation for safety-related SSCs is perceived as high by the utilities, but there is a graded approach. In France the efforts for issuing SSC documentation is perceived as high, even for non-safety SSCs. In Slovenia the level of efforts for QA documentation depends upon type, SC and safety function of the SSC indicating a graded approach as well. In Switzerland the efforts depend upon the type and SC of the SSC and the experience of the supplier. In Belgium the level of effort for issuing QA documentation for safety-related SSCs is generally perceived as high by the utility, but this is seen as necessary. In Finland utilities perceive the level of efforts to issue QA documentation for safety-related SSCs as high, even for SC3 SSCs. The same applies to Sweden, where utilities need to perform specific QA-routines for every supplier involving significant efforts with little or even no contribution to SSC end quality. In the Ukraine the level of efforts for issuing QA documentation is case dependent, but is generally perceived as high by the utility even for SC3 SSCs.

Question 7: Use of non-nuclear industry components and equipment for safety-related SSCs

The use of non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities is already possible in quite a number of European countries. In Slovenia a CGD procedure for the dedication of non-nuclear industry standard components and equipment for safety-related SSCs according to EPRI guidance no. 3002002982 [7] is in place and common practice. In Belgium CGD is allowed and corresponding procedures are in place and have been used before, but the efforts for CGD of non-nuclear industry standard components and equipment are perceived as not being necessarily lower compared to procuring nuclear-grade items directly. In Romania and Spain CGD is also allowed and the utilities plan for wider use of CGD in the future and currently run corresponding projects.

In France, Hungary and Switzerland non-nuclear industry standard components and equipment may in principle be used for safety-related SSCs following a CGD process, but this route is not pursued on a wide level. In Hungary components and equipment manufactured according to non-nuclear industry standards may be used for safety-related SSCs in nuclear facilities providing they meet the relevant requirements and the supplier is qualified. In the Czech Republic utility CEZ has developed a CGD procedure and forwarded it to the regulator for discussion. Based on the proposed CGD procedure CEZ plans trials by applying the proposed procedure to a number of different SSCs. In Switzerland the use of non-nuclear industry standards is allowed for SC3 SSCs if their original design is based on them.

In Finland and Sweden the use of non-nuclear industry standard components and equipment for safety-related SSCs is currently extremely difficult. But as mentioned in Sections 2.3 and 2.9 in both countries utilities currently run national projects with the aim of developing and implementing a systematic dedication and qualification process for using non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities, mainly for SC3 SSCs, but also some SC2 SSCs. The national regulators of both countries are involved as observers in the national projects and agree with their aims. In Ukraine the use of non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities is not allowed.

Question 8: Use of alternative nuclear codes or standards

Concerning the use of alternative nuclear codes and standards the picture is quite diverse in Europe. In Belgium the usage of SSCs designed and manufactured according to alternative nuclear codes and standards (in this case nuclear codes and standards other than U.S.-based codes and standards, e.g. ASME BPVC) is common practice and included in the regulatory guidance. Similarly, in Ukraine the installation of SSCs designed and manufactured according to alternative nuclear codes and standards in nuclear facilities was done before and the utility Energoatom has built up significant experience in this. Moving along this route requires quite some efforts for substantiation (proof that the alternative nuclear code or standard delivers the same result as if the normal nuclear code or standard would have been used) and approval from the regulator. In the Czech Republic, Finland and Romania the use of alternative nuclear codes and standards for the design and manufacturing of SSCs is also possible after substantiation, which requires some efforts. In Sweden utilities and licensees have yet not pursued in this direction, but the benefits of doing so are seen as high. In Switzerland only ASME and KTA are allowed, so the use of alternative nuclear codes and standards is only possible after showing compliance with ASME and KTA. In France alternative nuclear codes and standards (KTA and ASME) have been used for a number of SC2 and SC3 SSCs in the EPR currently under construction in Flamanville, but the target quality level for these SSCs is the one according to RCC-M resulting in issuing of additional specifications to complement the requirements of ASME / KTA to obtain the quality level according to RCC-M. In Slovenia the utility NEK needs to comply with Slovenian national regulation, which follows U.S. regulation, which itself heavily relies on and stipulates use of U.S. nuclear codes, standards and practices at implementation level. Utilities in Spain do not pursue and plan to use alternative nuclear codes and standards other than what they use at the moment.

Question 9: Use modern state-of-the-art technologies for safety-related SSCs

The use of modern state-of-the-art technologies (e.g. additive manufacturing) for safety-related SSCs is only possible in all of the above countries if these technologies are either covered by nuclear codes and standards or they have been nuclear qualified via extensive tests to demonstrate their robustness, reliability and safety function.

4 Conclusions

The received answers show that the utilities in the majority of European countries with NPPs in operation are significantly concerned about reduced supply chain support and resulting challenges like SSC obsolescence and difficulty in finding new suppliers. "Elaborative" maintenance and repair of already installed SSCs is the preferred path forward for utilities in most European countries. Only if "elaborative" maintenance and repair is not possible anymore then replacement with modern similar SSCs is performed requiring in most cases lengthy, costly and risky dedication and qualification processes and approval by the regulator. In some countries procurement of safety-related SSCs to replace currently installed ones is performed according to old legacy requirements because the original requirements have not changed, to avoid qualification uncertainties and risks or because the current regulation does not support a different, modern and more efficient way forward.

To solve the above supply chain issues the utilities in a number of European countries have performed or plan to perform CGD trials, have performed CGD for a number of safety-related SSCs before (e.g. Belgium, France and Switzerland), are in the process of developing and implementing own CGD processes to enable the use of modern high-quality non-nuclear industry standard components and equipment for safety-related SSCs in nuclear facilities (e.g. Czech Republic, Finland and Sweden) or plan to use existing CGD processes more widely in the future (e.g. Spain and Romania).

The utility of Slovenia, NEK, is not, or is only to a minor extent, affected by SSC obsolescence and does not have such difficulties in finding new suppliers compared to utilities of other European countries, despite running only one reactor. The key issue is that NEK has a continuous investment programme in place, participates in joint and proactive supply chain initiatives and has an established CGD process in place giving access to a sufficiently large pool of suppliers for all safety-related SSCs preventing it running into severe supply chain challenges. NEK work methods could be seen as a good example on how to resolve supply chain issues. However, whether this is the case needs further assessment going forward.

Thus having CGD procedures in place, either U.S.-based according to EPRI guide no. 3002002982 [7] as in Slovenia or own ones as it is aimed for in national nuclear industry projects in the Czech Republic, Finland and Sweden is key in solving the supply chain challenges currently facing European nuclear utilities, in particular for those that operate small fleets of reactors. The implementation and application of CGD processes requires quite some efforts by utilities, as the responsibility for assuring that the commercial item performs its safety function is shifted from the supplier to the utility or a third party organisation acting on behalf of the utility. But relieving the supplier from this task opens the door to new potential suppliers for utilities. The entry of new suppliers would in turn enable the use of modern high-quality SSCs in new build nuclear facilities as well as in the preventive and predictive maintenance to prevent failures of SSCs important to safety in the current European nuclear facility fleet.

If utilities decide to implement CGD, the approval of the respective national regulator is normally required, as national regulation most likely may need to be changed to allow the use of CGD. This means that a decision to move along this route has to be taken by all the nuclear stakeholders (utilities and regulator) in each country individually. If utilities of European countries decide to implement and perform CGD they should aim for wide cross-border collaboration including joint issuing of common and coherent documentation (e.g. technical specifications for SSCs) and data sharing from dedication processes and qualification tests of non-nuclear industry standard components and equipment, as it is planned between Finnish and Swedish utilities following their national projects. This would be a valuable contribution to the harmonisation of SSC documentation and CGD processes in Europe.

Ideally European utilities would perform CGD according to a common harmonised European approach or guidelines. Such an approach or guidelines would need to be

developed by European utilities in close interaction with European regulators based on international and European experience and accounting for European specifics. Developing such an approach or guidelines requires review of supply chain management practices, technical requirements (design, manufacturing) and QM practices for safety-related SSCs as well as benchmarking against technical requirements and QM practices of non-nuclear industries¹⁹.

Concerning the use of alternative nuclear codes and standards Belgium could be seen as a forerunner and possibly a good example to other European countries. However, this needs to be further assessed and documented in order for other European countries to benefit and build on the Belgian nuclear industry practice.

The use of non-nuclear industry standard components and equipment for safety-related SSCs after it went through a CGD process or the use of safety-related SSCs produced according to alternative nuclear codes and standards should not be limited to the current fleet of reactors, but should also become the common future best practice for new-build reactors, radioactive waste management facilities (e.g. for spent nuclear fuel) and even for future advanced reactors, i.e. SMRs and Gen IV reactors. Gen III/III+ and IV reactors are designed for 60 years and, considering the operating experience of the current fleet of reactors where LTO is common practice, operation of Gen III/III+ and IV reactors up to 80 years is a likely scenario. As the existence of OEMs of safety-related SSCs for such long time periods cannot be guaranteed and obsolescence of certain SSCs can be expected after a couple of years of operation (e.g. for I&C equipment), Gen III/III+ and IV reactors should be operated with CGD processes in mind straight from the start of the new build projects. Following this route for future advanced reactors straight from the beginning would avoid running into the supply chain challenges and legacy problems facing the current European facility fleet.

In the end it should always be remembered that the safety of nuclear facilities is ensured by high-level principles [16], requirements and concepts [17], e.g. the concept of Defence-in-Depth. The supply chain strategy of a nuclear facility is inseparably connected with nuclear safety considerations and is thus based on these high-level principles, requirements and concepts. Nuclear facilities are designed, constructed, operated and maintained for safe and reliable operation and their safety may not be jeopardised by a single failure, human error or a combination of these. To ensure this safety-related SSCs of a nuclear facility have to comply with the concepts of diversity²⁰, redundancy²¹, physical separation and functional independence [17] throughout the lifetime of the facility. This requires the timely implementation of preventive and predictive maintenance of nuclear facilities by use of modern SSCs of high quality and proven reliability, functioning when needed, from diverse and best available sources, including suppliers that offer and prefer producing SSCs according to non-nuclear industry standards or alternative nuclear codes and standards.

EC-JRC continues to investigate the greater use of high-quality non-nuclear industry standard components and equipment in safety-related SSCs of nuclear facilities and greater use of SSCs according to alternative nuclear codes and standards to address supply chain challenges currently facing European utilities. In this sense EC-JRC intends to contribute to the review of supply chain management practices, technical requirements (design, manufacturing) and QM practices for safety-related SSCs and benchmarking these against technical requirements and QM practices of non-nuclear industries, as it does already within ongoing nuclear codes and standards development activities (e.g. CEN Workshop 64). EC-JRC intends to organise workshops with European regulators, technical safety organisations (TSOs) and utilities to inform and support them in this area, and already plans to organise a workshop on CGD primarily for European

¹⁹ A detailed description of the tasks that need to be performed to enable widespread use of non-nuclear industry standard components and equipment for safety-related SSCs in European nuclear installations can be found in the FORATOM report on the topic (see [15]).

²⁰ Use of multiple different technologies to perform a single safety function.

²¹ A safety function can be performed regardless of failure of single SSC.

regulators and TSOs towards the end of 2020 together with EC-ENER. EC-JRC intends to contribute to planned European or international guidelines on CGD.

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²² Kärnkraftindustrins säkerhetskoordineringsgrupp (KSKG)

List of abbreviations and definitions

| | |
|-------|--|
| ANSI | American National Standards Institute |
| API | American Petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| BPVC | Boiler and pressure vessel code |
| CGD | Commercial-grade dedication |
| DiD | Defense-in-depth |
| DG | Directorate General |
| EC | European Commission |
| EN | European Standards |
| ENER | DG Energy of the EC |
| Foak | First-of-a-kind |
| GEN | Generation |
| IAEA | International Atomic Energy Agency |
| I&C | Instrumentation and control |
| IEC | International Electrotechnical Commission |
| ISA | International Society of Automation |
| ISO | International Standardisation Organisation |
| JRC | Joint Research Centre |
| KTA | "Kerntechnischer Ausschuss" (German nuclear codes & standards) |
| LTO | Long-term operation |
| NPP | Nuclear power plant |
| OEM | Original equipment manufacturer |
| PO&C | WANO performance objectives and criteria |
| QA | Quality assurance |
| QC | Quality control |
| QM | Quality management |
| SC | Safety class |
| SMR | Small modular reactor |
| SSC | Structures, systems and components |
| TSO | Technical safety organisation |
| WANO | World Association of Nuclear Operators |
| WENRA | Western European Nuclear Regulators Association |
| WNA | World Nuclear Association |

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