50 years of safeguards challenges from an SSAC point of view

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1. Abstract

The Safeguards Agreement between the IAEA and Hungary in implementation of Article III, (1) and (4) of the Treaty on the Non-Proliferation of Nuclear weapons was ratified by Hungary 50 years ago in 1972. Since then Hungary's safeguards system has been facing numerous challenges. The SSAC – to meet the international requirements – was established successfully and developed continuously by the Hungarian Atomic Energy Authority (HAEA).

Additional Protocol brought challenge e.g. to place our closed-down uranium mine under IAEA safeguards and provide information which was not required for the operating mine, or to de-exempt and include into the NMAC system nuclear materials which were exempted mostly 50 years ago etc.

The year 2004 when Integrated Safeguards system was introduced and in the same year Hungary joined to the European Union prompted us to rethink the role of SSAC.

During the years we met several technical challenges as well like to develop a safeguards system for dry storage of spent fuels from Paks NPP, a type of facility that was not under international safeguards at that time or reestablish the nuclear material accountancy of items from 30 spent fuel assemblies severely damaged due to an incident in the Paks NPP in 2013.

Challenges are not over. Safeguards culture and the commitment of the safeguards professionals are on the focus now. Hungary (HAEA) introduced Safeguards Performance Assessment Indexes and Comprehensive Domestic Safeguards Verification System as regulatory safeguards culture measures. Regarding the new nuclear power plant in Paks the application of safeguards by design (SbD) is essential. SbD guidelines were edited and workshops were organized by the HAEA to properly include safeguards criteria in the design submitted by the new NPP for the construction licence. Based on the analysis of the past 50 years, it can be concluded that the operation of national and facility level safeguards systems that met the requirements of the international nuclear safeguards regime and were responsive to the continuous challenges resulted in a win-win situation for both the international non-proliferation regime and the Hungarian nuclear industry.

2. Introduction

Last year was the 50-year anniversary of the ratification of the Comprehensive Safeguards Agreement between the IAEA and Hungary. The Additional Protocol was ratified by Hungary in 1999 and entered into force in April 2000, with Hungary being among the first countries with significant nuclear industry to implement it.

It took an additional 4 years for the integrated safeguards to be introduced by the IAEA in Hungary in 2004.

In May 2004 Hungary became member of the European Union and according to the accession treaty it also automatically became the member of the European Atomic Energy Community (Euratom). Since then the safeguards provisions set by the NPT for Hungary have been fulfilled by the multilateral safeguards agreement and additional protocol between the European Atomic Energy Community, the IAEA and the Member States.

In 2004, it was the combination of the introduction of the Integrated Safeguards system as well as Hungary's accession to the European Union which made us rethink the role of our SSAC.

The responsible organization for the supervision of the peaceful use of nuclear material is the HAEA which is responsible for the nuclear safety, security as well for radiation protection.

As a Technical Support Organisation (TSO) the Nuclear Security Department (NSD) of the Centre for Energy Research (former Institute of Isotope Research of the Hungarian Academy of Sciences) provides continuous and valuable support in the area of instrument development.

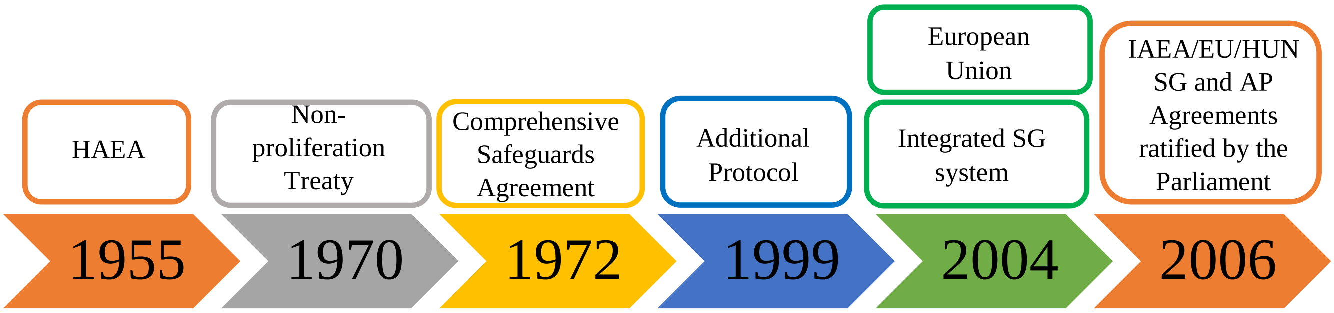

Fig. 1. Development of the Hungarian Safeguards System

3. Nuclear Profile of Hungary

The nuclear fuel cycle in Hungary is open in both ends, since there is no production of nuclear fuel, and the spent fuel is not reprocessed but stored in an interim storage facility. There are four WWER-440 type pressurized water reactors used for power production at Paks site currently.

The spent fuel of the power reactors are temporary (50 years) stored in the Spent Fuel Interim Storage Facility (SFISF) at Paks, which is a modular vault dry storage with passive air cooling.

Besides, there is a tank type research reactor of 10 MWth power operated by the Center for Energy Research (Budapest Research Reactor), and a 100 kWth powered pool type training reactor at the Budapest University of Technology and Economics (Training reactor, BUTE).

4. Safeguards challenges in the past

4.1. Developing safeguards measures for a type of dry storage facility which was not under international safeguards

At the beginning of the 90's Hungary followed a 'wait and see approach' for the safe management of spent fuel assemblies (SFA) in the units 1-4 of the Paks Nuclear Power Plant. It was decided that in addition to or instead of shipping back to Russia the spent fuel storage problem of the NPP would be solved by the construction of a GEC-Alsthom designed Modular Vault Dry Storage (MVDS) for a temporary period of 50 years in the vicinity of the NPP.

GEC-Alsthom constructed the original dry storage facilities in the UK and one was built in the USA as well. Neither of them, however, was under the International Atomic Energy Agency's safeguards.

Due to the lack of preliminary safeguards related experience, the task required a careful consideration of the possible safeguards strategies for this type of spent fuel storage. Therefore the IAEA, in close cooperation with the Hungarian Atomic Energy Authority (HAEA) and the operator, developed safeguards measures to be applied during the operation of the MVDS. The system included all safeguards measures to maintain the continuity of knowledge of SFAs to be stored in the facility.

4.1.1. Containment and surveillance (C/S) measures

Owing to the design of the MVDS, the SFAs in the Fuel Storage Tubes (FST) can only be accessed from the charge face by removing the shield plug of this FST. If the plug is sealed, the SFAs cannot be removed without tampering the seal. For this purpose, the shielding plugs of the FST had to be retrofitted with a size of hole required for the IAEA seal cables, for which the operator's assistance was provided. (The benefits of the safeguards by design methods did not receive the attention they do today during the design phases of our newly-built NPP.)

Application of containment and surveillance (C/S) measures was of primary importance to reserve the continuity of the safeguards related information of the SFAs. The first component of the relevant C/S system was the sealing of the C-30 type spent fuel transport cask by a VACOSS seal in the reactor hall. This point was monitored by a MIVS video system. Upon receipt of the C-30 container at the Transfer Cask Reception Building, the removal of the seal was monitored by another MIVS video system. At the cask load/unload port – which is the most important strategic point on the shipping route – a CONSULHA system was installed for monitoring the transfer of SF in unattended mode. This fuel transfer monitor consisted of a ^{3}He neutron detector, a fission chamber, two silicon detectors, the corresponding electronics and a data recording unit. The detectors to detect the spent fuel signatures were installed in the vicinity of the drying tube. The next component of the C/S system consisted of an EMOSS electronic cabinet (installed on the Fuel Handling Machine) and video signal splitting devices. These were used to split for the IAEA video signals of the two of the four identification cameras of the Fuel Handling Machine, in addition to the two navigation cameras. The video signal authentication and recording had to be ensured inside the EMOSS electronic cabinet. The surveillance of the charge hall was based on EMOSS image recording system.

The sealing system involved sealing together two rows of storage tube plugs (up to 29 pcs) and three support stools. The IAEA applied fiber optic Cobra seals and E-type metal seals as well.

4.1.2. Inspection system

The IAEA inspections were planned to include an annual PIV, quarterly interim inspections for timeliness, and interim inspection for the verification of transfers to the MVDS. In addition monthly interim inspection for the verification of transfers were planned for the equipment service and seal attachment during transfer campaign.

Due to the introduction of Integrated Safeguards in the Hungarian facilities and Hungary’s joining the Euratom in 2004 as well as thanks to the development of the technology used by the IAEA and the Euratom, the original safeguards measures applied in our MVDS have changed since 1997. C/S measures remained of primary importance and they are complemented with accountancy measures.

4.2. Portable Spent Fuel Attribute Tester (PSFAT) developed for safeguards verification at NPP Paks

From the middle of the 90’s with the financial support of HAEA the Institute of Isotope Research started development of a portable CdZnTe detector (PSFAT) which helped not only HAEA’s regulatory activities in safeguards related issues specific for Hungary but the IAEA was also able to meet the safeguards criteria for the verification of the spent fuel assemblies. The good co-operation between HAEA and IAEA in this field enhanced the efficiency of safeguards and was beneficial for both parties.

4.2.1. Verification of spent fuel assemblies with long cooling time, those with low burn-up as well as non-fuel items

The national regulatory and international safeguards systems faced several challenges to identify spent fuel attributes of spent fuel assemblies with 6-7 year cooling time which were stored in the spent fuel pond in the Paks NPP. The long storage time in the spent fuel pond was necessary because shipment of spent fuel assemblies back to Russia stopped and Hungary's spent fuel storage was not yet in operation. To help safeguards inspectors in cases when Cherenkov viewing devices were not usable a PSFAT was developed by the Institute of Isotope Research.

PSFAT was further developed in 1996 when slightly irradiated fuel assemblies were shipped from the Greiswald NPP (former East Germany) to the Paks NPP and placed into the spent fuel pond. Both nuclear power plants are of Soviet design with VVER-440/V-230 type reactors. Verification of these fuel assemblies with ICVD was difficult or failed. PSFAT was required to detect the spent fuel specific signatures of the extremely low burn-up Greifswald fuel assemblies in the spent fuel pond within reasonable measurement time even in the presence of other strong gamma-emitting fuel assemblies. The improved version of the PSFAT was equipped with a 500 mm^3 hemispheric CdZnTe detector and a modular collimator (max. lenght of 8 m). Test measurements and their comparison with the IAEA version of the PSFAT had to be performed. Following these measurements the Hungarian version of the PSFAT was accepted for routine use by the IAEA.

In 1999 PSFAT was further developed and tested for identification of non-fuel items in spent fuel pond of the Paks NPP, i.e. WWER-440 absorber assemblies and Co-60 sources produced during reactor operation and their holders were stored in the spent fuel pond of the NPP. The PSFAT provided an improved confidence level of spent fuel pond verification, by confirming the absence of fission products in non-fuel items.

The PSFAT was developed in the framework of the Hungarian Safeguards Support Programme (HUN SSP) to the IAEA safeguards, and was left sealed (by the Agency) in Paks NPP, authorized for IAEA inspection use.

4.3. Exempted materials

Before the signature of the Additional Protocol, in the period between 1972 and 1997, Hungary requested the IAEA for the exemption of small amount of nuclear materials from safeguards, the accountancy for which was only necessary to document that their total amount was below exemption level.

Even before the signature, Hungary started to prepare the declaration of the exempted materials according to 2a(vii) of the Additional Protocol. By the time of the deadline, the whereabouts of all the exempted materials could be traced and the relevant declaration submitted. After the accession to the Euratom, however, these materials had to be de-exempted and included into the nuclear material accountancy system, since their amount regionally exceeded the limit specified in the safeguards agreement.

4.4. Safeguard aspects of the closed uranium mine

For economical reasons the uranium ore production was stopped in the uranium mine of the Mecsek after 40 years of production and export of 20 tones of uranium in 1997, when the mine was closed. The produced ore and the ore concentrate were out of the scope of the traditional safeguards agreement between the IAEA and Hungary.

Due to the ratification of the Additional Protocol Hungary is obliged to provide information specifying the location, operational status, annual production capacity and actual production of uranium mines and concentration plants. Information must be provided also about source materials which have not reached the composition and purity suitable for fuel fabrication or for being isotopically enriched.

This led to the interesting situation that data provision was not required for the operating mine, but it is required for the closed mine under the Additional Protocol.

4.5. Reestablishment of the nuclear material accountancy for damaged fuel assemblies

On April 10, 2003, in the service shaft of Unit 2 at the Paks NPP 30 fuel assemblies were damaged seriously during the ex-vessel chemical cleaning process due to cooling failure and they became untreatable with the conventional tools used in the plant. During the restoration phase of the incident (2006-2008), parts of the damaged fuel assemblies were encapsulated into new casks, which resulted in an inhomogeneous mixture of fuel material with different burn-up values.

The international and national regulations provide clear requirements for the accountancy for and control of nuclear materials that must be met by Paks NPP as a nuclear facility. The most important one was the ability to account for the amount of nuclear materials with gram precision. For the determination of the nuclear material content of each cask, the development of an underwater NDA method was necessary. The technology was developed by NSD with close cooperation of the IAEA, the Euratom and the HAEA. Since no similar measurement case were known from the literature, the formulation of the principle of the method posed a significant task for both national and international experts.

The optimal solution was based on scanning the casks by gamma-spectrometry and neutron intensity measurement and the automatic evaluation of the great amount of data, for which a „FORK" type device was constructed.

Each cask was measured in upward and downward scanning mode from three sides resulting in 47 data package for each face (neutron intensity, gamma-spectrum and gross-gamma intensity), which required the evaluation of 36000 data packages in total. From the gamma-spectra the amount of fissile materials (^{235}U, total U and Pu) can be calculated. The amount of fuel material for a unit length of a cask could be determined from the neutron intensity and weight measurement data. Based on these results, the amount of nuclear material in each cask could be calculated with precision appropriate for the nuclear accountancy purposes.

The material balance refined with these measurements was produced for the Paks NPP by the NSD. The correctness of the nuclear accountancy reports of the casks was checked by the HAEA, and verified by the IAEA and the Euratom by NDA measurements of randomly selected casks.

4.6. Measurement of Pu-Be neutron sources

The determination of the Pu content of Pu-Be neutron generators is of major importance both from the correct nuclear accountancy and from nuclear forensics point of view. There were plenty of neutron sources of Russian origin in use in Hungary and their Pu content could only be calculated on the basis of the neutron-yield data provided by the supplier, which formed the base of their nuclear accountancy. The majority of these sources became disused and the measurements of their real Pu content were necessary before their shipment to a storage place.

To meet this request, the NSD, as the TSO of the HAEA, developed a measurement method. According to the method, the isotopic composition (atomic mass: 238, 239, 240, 241 and 242) was determined by high-resolution gamma-spectrometry (HRGS), the neutron yield is determined by gross- and neutron coincidence counting, which was later modified to use only neutron coincidence counting.

Applying this technique 76 disused, Pu-Be neutron generators kept in old container with expired license were measured. The measured sources were placed in new stainless steel containers designed and licensed for neutron sources (ISO 9001) with engraved identification number.

Based on the results of the measurements, the original Pu content of 76 sources had to be significantly modified (from 2050 g to 563 g). The method was offered for the IAEA under the HUN SSP and it is also applicable for nuclear forensics purposes.

4.7. Participation in the Global Threat Reduction Initiative (GTRI) Russian Research Reactor Fuel Return (RRRFR) programme

The Budapest Research Reactor took part in the GTRI RRRFR program of the US Department of Energy, during which its highly enriched uranium spent fuel elements were repatriated in 2008, and 2013 and the highly enriched uranium fresh fuel elements were transported back to Russia in 2009. The active involvement of Hungary in the program facilitated the reduction of the risk of proliferation of nuclear weapons and contributed to the strengthening of the non-proliferation regime.

The facility was to provide advance notification on the entire schedule of safeguards relevant activities connected to the repatriation project. Daily reports on the actual activities (mail-box approach) in course of the loading campaign were also requested by HAEA. The facility was also requested to assure free access of the HAEA inspectors to the site without advanced notification, during which the content of the daily reports and conditions of the international inspections could be verified. Compliance with information reported in advance (schedule of loading, change in activities) was sufficiently controlled by the HAEA on announced and unannounced basis to optimize its human resources.

During the repatriation, harmonization of the IAEA, the Euratom and the HAEA inspections was of primary goal in order not to disturb the work of the operators. For the optimization of the inspection effectiveness surveillance and containment safeguards measures were applied simultaneously. Each fuel element item was verified before loading to the shipping container by batch number and gamma-spectrometry. The measurement data were shared between the IAEA, the Euratom and the HAEA to make independent conclusions. For the surveillance of the loading hall, the IAEA installed a camera, shipping containers were sealed with IAEA/Euratom common seals

The Hungarian SSAC could not only satisfy its safeguards requirements as a signatory to the NPT, but could also act as a facilitator between the operators and the IAEA/Euratom inspectors creating optimal conditions for their verification activities. Satisfying safeguards requirements on three different levels could be performed with due attention to the operators' interests and to avoid duplication of efforts.

5. Safeguards challenges in the present and in the future

5.1. Safeguards Culture

Challenges are not over. Safeguards culture and the commitment of the safeguards professionals are on the focus now. Despite there is no generally accepted definition of safeguards culture, HAEA considers that the commitment to the peaceful use of nuclear materials in personnel, organisational, facility and state (national) level is essential to maintain an effective safeguards system. To strengthen and estimate – since it is not quantifiable – the effectiveness of the safeguards culture in Hungary HAEA introduced three tools in the last decade:

1. Comprehensive Domestic Safeguards Verification System,
2. Safeguards Performance Assessment Index,
3. Annual Safeguards Forum.

5.1.1. Comprehensive Domestic Safeguards Verification System

Based on very promising experiences in the field of nuclear safety in 2010 HAEA has introduced a comprehensive domestic safeguards verification system consisting of regular comprehensive SSAC verifications in the whole lifetime of the facilities.

Verification of the management systems (highest and safeguards management) as well as safeguards relevant area: operation and maintenance, accountancy and data provision were selected for verification.

The main goal was defined as follows: to review whether the facility level safeguards system of the organization is run in compliance with the relevant legal instruments and recommendations. Before conducting the on-site verification, all the legal documents, policies, strategies, internal procedures are reviewed by the HAEA to validate the facilities' safeguards tasks are formally documented internally. The results of this review as well as good practices for promoting safeguards knowledge and awareness are discussed during the on-site verification.

During the last few years, the Safeguards Section of the HAEA conducted comprehensive safeguards verifications in all of the four Hungarian nuclear facilities annually on a rotation basis. In 2015 the experience collected, and evaluated was shared with the safeguards representatives of the facilities during the annual safeguards forum organised by the HAEA. In 2016, HAEA continued to carry out the CDSVS focusing on the sustainable maintenance of the already defined good practices and correction of the previously identified deficiencies. In 2020 the experiences of the second cycle of the comprehensive safeguards verifications were collected and evaluated. From 2021 HAEA started a new cycle again.

5.1.2 Safeguards Performance Assessment Index

In 2015, the Hungarian Atomic Energy Authority introduced Safeguards Performance Assessment Indexes (SPAI) to evaluate the annual performance of the nuclear safeguards system of the nuclear facilities. The aim of these indexes was the timely detection of occurring changes and deviations from the optimal operation as well as early identification of issues to enable the prevention of more serious occurencies allowing for timely response.

The parameters included in SPAI were developed for performance assessments, which are already available, easily accessible and collectable from the inspection records, licensing procedures and reports submitted by the facilities. In general, the HAEA does not have to use additional resources or collect additional information, only the available data and their circumstances have to be assessed and analysed.

The areas assessed by SPAI for nuclear facilities cover three major parts of the facility safeguards system, such as (i) safeguards organization; (ii) operation of the safeguards system; (iii) safeguards licensing procedures.

The evaluated parameters include e.g. training requirement for safeguards staff, quality of safeguards reporting for IAEA and European Commission, and results of safeguards inspections.

The HAEA first used the SPAI to assess the safeguards system of the nuclear power plant in Hungary, however, from 2017 all of the four Hungarian nuclear facilities were evaluated by using the indexes.

Based on the experiences since 2015 the early results have been promising. The method may be used for example to alert our authority when the decrease in the number of the safeguards staff of the facility may result in a weakened safeguards system.

The SPAI as metrics proved to be a very useful tool for the regulatory assessment of how safeguards are managed and operated at the facility level.

5.1.3. Annual Safeguards Forum

In 2014 HAEA introduced the annually held safeguards forum to provide an expert level meeting for the professionals, who are committed to the peaceful use of nuclear energy. Participants include the safeguards responsible people and managers from the Hungarian material balance areas, (not only the facility representatives) as well as representatives of HAEA's and TSO's. The forum gives the opportunity to share the challenges and experiences in the field of nuclear safeguards in all level (MBAs, facilities, state). HAEA every year presents the previous year's most important international and national safeguards related events, tasks, statistics but also offers the chance for the participants to introduce their safeguards organisations, ask questions and make comments.

The annual safeguards forum helps to create a safeguards professional community which is essential for country's safeguards awareness.

5.2. Safeguards by design at our planned NPP

Regarding the new nuclear power plant in Paks the application of safeguards by design (SbD) is essential. In order to facilitate the inclusion of the 'safeguards by design' concept into the project well in advance, HAEA identified several tasks: (1) update of the national safeguards related requirements; (2) preparation of a guideline on how to fulfil the new national requirements and (3) set up a taskforce to facilitate the 'safeguards by design' with the involvement of all stakeholders.

'SG-2 Guideline for newly built reactor' was issued specifically on safeguards requirements in new NPPs in June, 2015, after the bilateral agreement on co-operation in the field of peaceful use of nuclear energy between the Government of Hungary and the Government Russian Federation was concluded.

The guideline gives recommendations on how to fulfil national legislation when implementing safeguards in new nuclear power plants. Details of obligations to provide advance information to meet design and installation requirements in case of a new NPP to ensure its safeguardsability are described. Requirements detailed in the guideline include obligations undertaken under IAEA and EURATOM safeguards system as well as the relevant IAEA documents in the field of safeguards by design.

The guideline briefly introduces the basic objectives of safeguards and describes how to meet these objectives on facility level. It advises on use of proliferation resistance technical solutions, to maintain strict nuclear material accountancy, to put into effect data provision obligations, and to ensure timely detection of diversion and/or misuse and deterrence through risk of early detection.

One of the key objectives of the HAEA is to take into account the requirements and recommendations of the safeguards system at all stages of the design of the newly built nuclear power plant units.

The first international safeguards by design workshop with international and national stakeholders was organized by HAEA in 2018. Regular meetings are held for stakeholders, including IAEA and Euratom, to discuss any emerging safeguards issues and requirements to meet them.

Safeguards relevant assessment of Basic Design was made by HAEA from January to April 2020. In June 2020 the application for the Construction License (CLA) was submitted to the HAEA by the new NPP with a newly updated BTC. The CLA was assessed by the HAEA with view of safeguards requirements. The assessment included findings on comparison between data included in the BTC and those in CLA and on checking the completeness of the safeguards requirements. The findings were sent to the new NPP who made the proposed modifications in their CLA. In August 2022 the construction license was issued by HAEA. To include more concrete safeguards specifications into the currently developed detailed design, the process will be supported by the Equipment Infrastructure Requirements document (EIR) which is expected to be finalized in the coming months by the Euratom, IAEA and the Hungarian stakeholders.

6. Summary

The 50th anniversary of the Hungarian safeguards system provided good opportunity for HAEA to look back on the challenges the authority faced when meeting its international safeguards obligations.

The challenges of the past 50 years did not just represent the everyday safeguards tasks of the authority but were beyond that and also required close cooperation with small nuclear material holders and nuclear facilities. Several of our challenges required to develop new equipments or new measurement methods while others were aimed at introducing measures to further increase the efficiency of the current or the future implementation of the facility and national safeguards system thus contributing to a more robust international safeguards regime. The TSO of HAEA played an important role in developing measurement methods and equipment to identify nuclear material content of confiscated and accidentally found materials or spent fuel attributes of nuclear fuel assemblies in cases where Cherenkov measurements failed.

From 2010 HAEA introduced new tools and measures to strengthen and estimate the level of safeguards culture at Hungarian safeguards facilities. Comprehensive Domestic Safeguards Verification System was introduced in 2010, to verify the commitment (both on personnel and on organisational levels) to nuclear safeguards. Annual Safeguards Forum was introduced in 2014, to create a safeguards professional community and a Safeguards Performance Assessment Index was introduced in 2015, to measure the annual performance of a facility’s nuclear safeguards system.

Based on the analysis of the past 50 years, it can be concluded that the operation of national and facility level safeguards systems that met the requirements of the international nuclear safeguards regime and were responsive to the continuous challenges resulted in a win-win situation for both the international non-proliferation regime and the Hungarian nuclear industry.

The next 50 years are expected to bring us further challenges, however, they will make our safeguards system even stronger.

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