KINGDOM OF BELGIUM

EIGHTH MEETING OF THE CONTRACTING PARTIES TO THE CONVENTION ON NUCLEAR SAFETY

NATIONAL REPORT

August 2019

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This report is produced by the Federal Agency for Nuclear Control on behalf of Belgium. Contributions to the report were also made by "Bel V", "ENGIE Electrabel", "Tractebel ENGIE" and "SCK•CEN".

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I. Introduction

I.A. Content of the Present Report

This Belgian national report, submitted for the eighth review meeting of the contracting parties to the Convention on Nuclear Safety (CNS), is based on its previous editions and has a similar structure. For each article of the Convention, relevant descriptions and explanations are provided on how the principles of the Convention are translated into the Belgian legal framework and how they are applied to its nuclear installations. In addition, in order to highlight relevant evolution since the last review meeting, section I.C focuses on new developments since 2016.

Section I.D lists planned actions to improve safety from 2019 onwards.

When drafting this report, due account was taken of the appropriate guidelines in INFCIRC/572/Rev.6 (19 January 2018).

On a voluntary basis, information about the Belgian research reactors is included in the present National Report. The post-Fukushima actions for the research reactors are also described.

To keep the report to a reasonable size, rather than identifying for each Article the particularities and characteristics of the Belgian power plants, it was deemed preferable to give in Appendix 1 a detailed description of the power reactors, highlighting their original design and the major modifications brought to them during the periodic safety reviews, which are mandatory under the Belgian regulations. 0 contains similar information about the BR1 and BR2 research reactors.

A list of the acronyms used in the present Report is given in 0.

Appendix 4 gives the web site addresses of Belgian organisations playing an important role in the nuclear field.

Appendix 5 lists the subjects which have been examined during the 10-yearly safety reviews of the Doel and Tihange units.

Appendix 6 gives an overview of the action plan as a result of the European stress test process.

The principal nuclear Belgian actors have participated in drafting the present National Report:

- FANC, the Federal Agency for Nuclear Control, the safety authority,
- Bel V, the technical subsidiary of the FANC,
- ENGIE Electrabel as the licensee and operator of the seven nuclear power plants,
- Tractebel ENGIE, the engineering support organisation to the NPP's operator,
- SCK•CEN, as the operator of the research reactors in Belgium.

Together, the above-mentioned organizations encompass the legal and practical competencies necessary to collect and to structure the information required to elaborate the national report.

The report is available on different Belgian web sites such as www.fanc.fgov.be, www.belv.be.

I.B. History of Nuclear Energy Development in Belgium

Before the Second World War, Belgium was the world's largest radium producer, which gave rise not only to the related metallurgy, but also, in collaboration with the academic circles, to the development of metrology techniques. In the universities several teams worked on the latest discoveries in the field of particle physics and maintained close contact with their counterparts abroad.

By 1945, a Scientific Commission in Belgium examined the possibilities of civil applications of nuclear energy, and the "Institut Interuniversitaire de Physique Nucléaire" was created in 1947 to support the existing university laboratories and coordinate their activities. In parallel with nuclear physics research, this Institute also supported some related activities such as production of graphite and high-purity metallic uranium.

From 1950 onwards, Belgian engineers were trained in the UK and in the USA.

The Atomic Energy Commission was formed in 1950.

In 1952, several personalities of Belgium's scientific and industrial circles set up a private non-profit organisation -the "Centre d'Etude des Applications de l'Energie Nucléaire"-, which was to give birth to the "Centre d'Etude de l'Energie Nucléaire" (SCK•CEN) at Mol (i.e. the Nuclear Energy Research Centre), and which became a public interest organisation in 1957.

Research reactors were built in Mol and became operational between 1956 and 1963. These are the BR1, a uranium/graphite reactor similar to the British experimental pile (BEPO), the materials test reactor BR2 (fuel assemblies with highly enriched uranium placed in a beryllium matrix shaped as a hyperbolic paraboloid, which ensures at the same time a high neutron flux and an easier access to the experiments from the top and the bottom of the reactor) and the 11.5 MWe BR3 which was the first Westinghouse-type pressurised water reactor built in Europe. This reactor, which went critical in 1963, served to develop the technology (e.g. reactivity control by boron dissolved in the water of the primary circuit, introduction of MOX and gadolinium fuel rods as early as 1963) and to train the first operators of the Belgian nuclear power reactors. The BR3 is now nearly completely dismantled.

From 1950, the private industry has also invested in nuclear technology and participated in the construction of reactors. The "Ateliers de Constructions Electriques de Charleroi" acquired the Westinghouse licence; "Métallurgie et Mécanique Nucléaires" manufactured enriched uranium fuel assemblies, and later became part of the "Franco-Belge de Fabrication de Combustibles" (FBFC).

Regarding the fuel cycle, the Mol Centre investigated several reprocessing techniques which resulted in the Eurochemic Consortium – formed under the aegis of the NEA (OECD) – building its pilot reprocessing plant (adopting the PUREX process) in the Mol-Dessel region. This plant ceased its operations in 1975 and is now dismantled.

A consortium of industries was formed in 1954 to develop the nuclear technology; later giving birth to Belgonucleaire which developed the plutonium fuel technology. Belgonucleaire manufactured the first commercial MOX (Mixed Oxides) fuel batch for the French PWR power station Chooz A in 1986.

After having produced MOX fuel for 20 years, for both PWR and BWR reactors, Belgonucleaire definitively stopped its activities in mid-2006. Belgonucleaire produced more than 660 tons of MOX fuel for commercial nuclear power reactors. The dismantling of the MOX fuel fabrication plant at Dessel started in 2009. Clearance of the buildings and of the site should occur in 2019.

In 1971, the "Institut des Radioéléments" (IRE) was built in Fleurus, manufacturing mainly radioisotopes for use in medicine. This facility is still in operation.

The Belgian power utilities and their architect/engineers closely followed-up the evolution in nuclear technology and, confident with their BR3 experience, they decided to take a 50 % stake in the construction of EdF's "Centrale des Ardennes" at Chooz, connected to the grid in 1967. Seven Belgian units, spread over the Doel and Tihange sites, were put into service between 1974 and 1985.

The "Organisme National des Déchets Radioactifs et des Matières Fissiles Enrichies" – "Nationale Instelling voor Radioactief Afval en verrijkte Splijtstoffen" (ONDRAF/NIRAS) (i.e. the national organisation for radioactive waste and enriched fissile materials) was created in 1981, and waste treatment and storage activities were performed at the Mol-Dessel site through its subsidiary BELGOPROCESS.

This brief historic overview shows that, in addition to the nuclear power plants which are the subject of the present National Report, various aspects of the fuel cycle were present in Belgium.

Specific information on the safe management of spent fuel and on the safe management of radioactive waste may be found in the Belgian report presented to the sixth review meeting of the Joint Convention, Vienna May 2018, available on the FANC, ONDRAF/NIRAS and IAEA web sites.

Figure 1 : Nuclear sites in and near Belgium

The 7 NPPs on the Doel and Tihange sites are operated by ENGIE Electrabel, a member of the ENGIE group, created after the merger in 2008 of the 2 groups "Gaz de France" and "Suez".
In 2016, GDF Suez changed its name and became ENGIE.

Table 1 and Table 2 give the main characteristics of the 7 Belgian NPPs:

Units	Type	Thermal power (MWth)	Date of first criticality	Containment building characteristics	Steam generator replacement	Fuel storage pool capacity	Designer
Doel 1	PWR (2 loops)	1 312	1974	Double containment (steel and concrete)	2009	664 positions	Westinghouse
Doel 2	PWR (2 loops)	1 312	1975	Double containment (steel and concrete)	2004		Westinghouse
Doel 3	PWR (3 loops)	3 064	1982	Double containment with inner metallic liner	1993	672 positions	Framatome
Doel 4	PWR (3 loops)	3 000	1985	Double containment with inner metallic liner	1997	628 positions	Westinghouse

Table 1 : Main characteristic of the units located at the Doel Site

Units	Type	Thermal power (MWth)	Date of first criticality	Containment building characteristics	Steam generator replacement	Fuel storage pool capacity	Designer
Tihange 1	PWR (3 loops)	2 873	1975	Double containment with inner metallic liner	1995	324 positions + 49 removable positions	Framatome / Westinghouse
Tihange 2	PWR (3 loops)	3 054	1982	Double containment with inner metallic liner	2001	700 positions	Framatome
Tihange 3	PWR (3 loops)	2 988	1985	Double containment with inner metallic liner	1998	820 positions	Westinghouse

Table 2 : Main characteristic of the units located at the Tihange Site

Article 4 of the **law of 31 January 2003 on nuclear energy phase out**, limited the operational period of the Belgian NPPs to 40 years. However, to ensure the electricity supply of Belgium, the government and the parliament modified article 4 of this law in 2012 and in 2015, to allow a long-term operation of Tihange 1 and Doel 1 & 2 units by 10 years.

The legal deactivation dates of the Belgian reactors are given in table 3:

Doel 1	15nd February 2025
Doel 2	1st December 2025
Doel 3	1st October 2022
Doel 4	1st July 2025
Tihange 1	1st October 2025
Tihange 2	1st February 2023
Tihange 3	1st September 2025

Table 3: Shutdown dates of the Belgian reactors

The construction of new NPPs in Belgium is forbidden by this law (Article 3).

I.C. Summary of the developments since the last report

This section focusses on new developments since 2016.

This section also addresses issues raised during the Belgian presentation at the last review meeting and reported in the Country Review Report for Belgium, as reproduced in table 4:

Challenges as reported during the 2017 review meeting	**Ref. in this report**
Challenge 1: The Regulatory body to complete the new national Nuclear Emergency Plan.	I.C.1.a)(2)
Challenge 2: The licensee to execute ongoing action plans (safety culture, stress tests, LTO, fire hazard analysis and PSA, WENRA 2014 safety reference levels) and the regulatory body to conduct appropriate oversight.	I.C.3
Challenge 3: The regulatory body and the licensee should complete preparations to support the final shutdown and subsequent decommissioning.	I.C.2
Challenge 4: Belgium to finalize the implementation of the IRRS action plan.	I.C.6.c)
Planned measures as reported during the 2017 review meeting	
Several changes to the regulatory framework and the national nuclear programme, including, among others: • The incorporation into Belgian regulations of the WENRA 2014 Safety reference Levels and of the European Directive 2014/87/EURATOM amending Directive 2009/71/Euratom. • The incorporation into Belgian regulations of the European Union´s Basic Safety Standards (EU BSS). • The completion of the new national Nuclear Emergency Plan.	I.C.1
Safety Culture Action Plan.	I.C.3.a)
Efforts within safety research and development (R&D) focusing on: Severe Accidents Progression, Seismic Hazard Assessment and Fire Protection.	I.C.8
The operator has planned several actions to improve safety for the next review period 2016-2019.	I.C.3

Table 4: Challenges and planned measures as reported for Belgium at the 2017 review meeting

I.C.1. Changes to the regulatory framework

a) New regulations issued during the period 2016-2019:

(1) The National declaration regarding nuclear safety, nuclear security and radiation protection

As a response of the recommendation n°8 of the IRRS hosted in Belgium end 2013, the Government issued the National declaration regarding nuclear safety, nuclear security and radiation protection. This declaration has been published in the Belgian Official Journal on 12 October 2018. It addresses the following topics:

- the principle of continuous improvement;
- the principle of justification;
- the principle of defense in depth;
- the safe management of radioactive waste;
- the coordination between the different bodies having responsibilities in nuclear safety and security;
- the requirement of a high level of competency;
- the need to ensure a transparent communication;

(2) The new national nuclear and radiological emergency plan

On March 1st, 2018, the new Belgian Nuclear and Radiological Emergency Plan (NEP) was published as a Royal Decree in the Official Journal. The new NEP integrates the lessons from past exercises and events (IRE 2008, Fukushima), the results of dedicated working groups, international recommendations and requirements such as GSR-7, GSG-11, the European BSS, the HERCA-WENRA approach and the advice from national Scientific Committees and other stakeholders (local and regional authorities and Greenpeace Belgium).

Before being published, the draft NEP was submitted for comments to a large panel of Belgian interested parties including Scientific Committees and other stakeholders (local and regional authorities, emergency services, licensees and NGO's).

The new NEP redefines its scope to include all operational Belgian Class I facilities and all foreign facilities within 100 km from the border. It also considers emergencies created by terrorist or malevolent action as well as accidents during the transport of nuclear fuel or waste from fuel reprocessing. To improve the communication with neighbouring countries and international bodies, the new NEP adopts the classification systems of GSR-7 and translates the notification levels previously used in facility emergency (former N1 level), site area emergency (former N2) and general emergency (former N3). The former notification level NR is kept and translated as general emergency in reflex mode.

The management structure has been slightly adapted to reinforce the principle of integrated crisis management and graded approach. At the federal level, the decision is entrusted to a Management Cell (Ministers) based on a global analysis of the situation (radiological, socio-economic, available resources…) provided by a Federal Coordination Committee. This committee is also in charge of following up the decision's implementation. The role of local actors (mayors and governors) is reinforced in a way that they can take operational decisions to protect their population provided they consult with the Federal Coordination Committee. More emphasis is also given to the later phases of an emergency (i.e. transition to the declaration of the end of the emergency) and the post-accidental phase, describing the changes in the management structure and the required flexibility to adapt to the evolution of the situation.

The updated emergency plan introduces the HERCA-WENRA approach concept of planning zones and extension zones. In this regard, the pre-distribution in pharmacies of ITB agents (Iodine Thyroid Blocking - KI tablets) has been extended up to 100 km from each concerned facility (Belgian operational Class I facilities and foreign NPPs), i.e. the whole country. Each Belgian family or responsible of a public or private establishment is strongly advised to collect tablets for the people which could be present in their house or establishment, especially if there are children amongst them.

(3) The Law of 7 May 2017 on Health Physics organization

This law amends the law of 15 April 1994 (see article 8 of the Convention related to the legal and regulatory framework). In particular, this law:

- Allows the Government to publish a National declaration regarding nuclear safety, nuclear security and radiation protection;
- States the first responsibility of the licensee for its activities;
- Requires each licensee to set up a health physics department (HPD);
- Allows the FANC to issue binding technical (non-policy) regulations, in matters fixed by Royal Decree;
- Provides a legal basis for Bel V as part of the regulatory body.

This new law also resolved three recommendations from the 2013 IRRS mission in Belgium.

(4) The Royal Decree of 6 December 2018 on Health Physics Control organization and regarding Bel V

This Royal Decree has been signed by the King on 6 December 2018. It was published in the Belgian Official Journal on December 21st, 2018. This Royal Decree amends the existing regulations on health physics organization (the Royal Decree of 20 July 2001 laying down the *General Regulations regarding the protection of the public, the workers and the environment against the hazards of ionising radiation* (hereafter "GRR-2001")) and legally set up the missions and responsibilities of Bel V, the technical subsidiary body of the FANC. This legislative adaptation was made to provide greater clarity for both nuclear licensees and transport operators and for authorized inspection organizations (AIOs). The Royal Decree also integrates the concepts of Radiation Protection Officer "RPO" and Radiation Protection Expert "RPE" as defined in the Directive 2013/59/EURATOM laying down the basic standards for protection against the dangers associated with exposure to ionizing radiation, and through this decree, the relevant provisions of this Directive are therefore transposed into Belgian law.

The principles on which the new regulation is based are:

- A clear separation between the regulatory body and the licence holder. Regulatory supervision belongs only to the FANC and its subsidiary body Bel V (in facilities of Class I and IIA).

- Prime responsibility of the operator or the company head for Health Physics. A Health Physics Department must always be organized within the licensee of operator's organization.
- A flexible and effective system that allows licensees or transport operators to call upon the expertise of recognized experts and/or on an authorized organization to ensure an effective radiation protection and nuclear safety of their installations and/or activities. Each licensee or transport organization is therefore given the freedom by the legislator to arrange its Health Physics Department in the way that best suits its organization.
- A sustainable and transparent legal and regulatory framework for Bel V, which clearly positions it on the regulatory side by assigning it supervisory missions by direct delegation from the FANC.

The impact for the installations covered by this Convention (NPPs) is however limited. The Health Physics Departments of the licensees are already in place and mostly in compliance with the new regulation. The role of the Health Physics Department is reinforced with some tasks related to nuclear safety and waste management. Bel V was established in 2008 as the technical subsidiary of the FANC. The missions and the working of Bel V are now more transparent for the concerned operators. In practice the missions of Bel V for the installations covered by this Convention remain unchanged.

(5) The Royal Decree of 29 May 2018 aiming to avoid situations which can give rise to possible liabilities of radioactive waste or of installations to be dismantled

This Royal Decree is focused on transfer of licences and on waste management and dismantling. It addresses certain recommendations of the 2013 IRRS-mission and aims at increasing the accountability of the operator for its radioactive waste and dismantling liabilities (see the Belgian National Report for the Joint Convention 2017 for more details). In particular, it:

- addresses the transfer of licences for facilities and activities;
- requires a "Radioactive Waste file" and a "Decommissioning file" as part of the licence application file. ONDRAF/NIRAS gives its advice on these files to the FANC in the frame of the licensing process;
- requires the Licensee to maintain a full inventory of all radioactive substances present in its installations;
- allows the FANC to order evacuation of unused (for 5 years) radioactive substances;
- requires a surveillance of the filling level of on-site waste storage installations, with a notification to the FANC in case of unexpected exceedance of a predefined level.

(6) The Royal Decree of 9 October 2018 completing the transposition of the Nuclear Safety Directive 2014/87/EURATOM

This Royal Decree aims mainly at including the Nuclear Safety Objective of article 8.C of the Directive 2014/87/EURATOM which is similar to the Vienna Declaration in the Belgian regulations, by amending the Royal Decree of 30 November 2011 *on the safety requirements of nuclear installation* (hereafter "SRNI-2011"). References to the Nuclear Safety Objective are made in the Periodic Safety reviews and in Experience Feedback requirements. The safety and radiological objectives related to the Nuclear Safety Objective are defined in a FANC guidance and were presented in the previous edition of this report.

b) Regulatory projects still in development

(1) The proposal of royal Decree related to the design of existing reactors, their protection against natural hazards and other requirements, that include the WENRA 2014 safety reference levels

As a result of the Fukushima-Daiichi accident, the Western European Nuclear Regulators Association (WENRA) was tasked to review the safety reference levels for existing reactors. The Reactor Harmonization Working Group (RHWG) issued, in September 2014, a revised set of reference levels (SRLs).

The FANC started in 2015 a new regulatory project to translate the new WENRA safety reference levels into the Belgian regulations. The regulatory project will be a major update of the existing Royal Decree on the safety requirements of nuclear installations (30/11/2011).

Currently, the FANC proposal is finalized. After stakeholders consultation, it has been sent to the Minister of Home affairs, for consultation of the European Commission and further enactment.

(2) The proposal of Royal Decree transposing the Directive 2013/59/EURATOM (the European Basic Safety Standards)

This project is still in progress. It aims at transposing several aspects of the new European BSS, including: new dose limits, new exemption and clearance levels and several provisions related to medical applications of ionizing radiations. The internal draft has been finalized at the FANC in October 2018. It is currently submitted to official advisory organizations, including the Superior Health Council, the national federation of hospitals, … After reception of these advices, the draft will be adapted, sent to the European Commission for advice and finally to the Council of Ministers for enactment.

I.C.2. Preparations to support the final shutdown of NPPs and subsequent decommissioning

Every 3 years **ENGIE Electrabel** prepares a Preliminary Decommissioning Plan for each of the nuclear sites, for which the most recent update is under finalization in 2019. This plan is the basis for the Final Decommissioning Plan for the different units to be decommissioned.

In 2012 ENGIE Electrabel started with the preparation of the decommissioning of Doel 1 and 2 (D&D D12). This project was stopped end of 2014, just before the start of the Post Operational Phase, as there was a governmental decision to extend the life of Doel 1 and 2 by 10 years.

In 2018 ENGIE Electrabel started with the program for the preparation of the decommissioning of the Belgian nuclear fleet (Fleet D&D) with a focus on Doel 3 and Tihange 2 as these are the first units to be taken out of service end of 2022 and beginning of 2023 respectively.

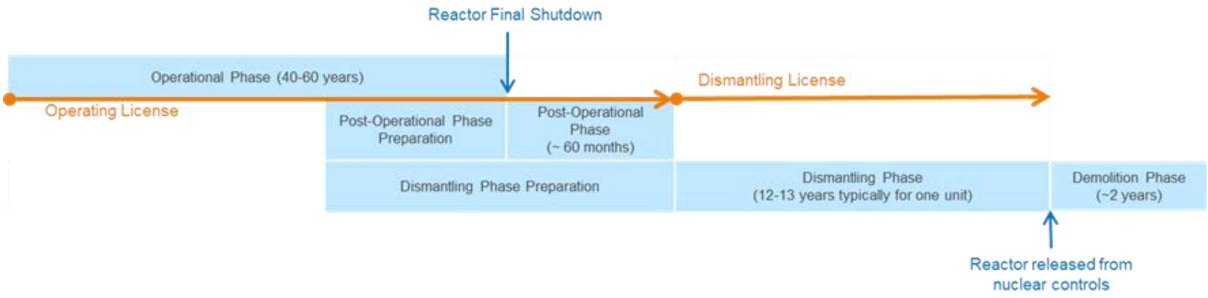

Figure 2: Timeframe for decommissioning and dismantling of NPPs

Currently the program focuses on the preparation of the Post Operational Phase of Doel 3 and Tihange 2, on the identification of the infrastructures needed to support dismantling and waste management activities and on the preparation of the Final Decommissioning Plan and the subsequent dismantling licence request. The methodologies developed for the preparation of the Post Operational Phase of Doel 1 & 2 are being implemented to prepare the Post Operational Phase of Doel 3 and Tihange 2. The Fleet D&D program benefits from experience feedback from Doel 1&2 which were initially planned to be decommissioned in 2015 and from other operators visited in the framework of this program. Furthermore, the Fleet D&D program has established contacts with other operators to be visited in the future for exchanges on most recent experience feedback. Discussions on the preparation of the decommissioning have been initiated with the Belgian Safety Authorities and Waste Management Organization (NIRAS/ONDRAF).

In view of the future decommissioning of the Belgian nuclear power, the **regulatory body** started an internal competence building project in 2014. The purpose of this project is to develop and define a clear and structured approach for the regulatory body, covering all aspects of decommissioning and dismantling waste issues.

The project also deals with the training of sufficient staff of the regulatory body on decommissioning activities and for the preparation of specific decommissioning processes.

This project deals with five issues:

- Building knowledge and experience on decommissioning activities and on waste from decommissioning;
- Licensing and safety assessments during the post-operational and decommissioning phases of an installation or facility;

- Regulatory supervision and inspections during the post-operational and decommissioning phases of an installation or facility;
- Special attention to waste and to waste management from decommissioning;
- Release of buildings and/or of site and end of regulatory control

Several reference documents have been produced by this project that is still in progress.
The FANC also established standard conditions that should be part of any dismantling licence and information about the end of regulatory control.

Bilateral contacts with foreign safety authorities have been established in the past years. These contacts will continue during the next years.

In 2018, the FANC started discussions with ENGIE Electrabel about the future decommissioning of its plants. The main purposes of those meetings are to clarify strategic decisions on (1) the "post-operational phase", (2) the preparation of the dismantling licence or (3) to discuss the basic design of possible new facilities that will be needed on site to carry out the dismantling.

For point (1), article 17/1 of the SRNI-2011 requires a notification of permanent shutdown. Regarding this notification, most of the discussion focussed on:

- the description of plant modifications during the Post Operational Phase (adaptations to the Safety Analysis Report (SAR) and the Technical Specifications);
- the measures to maintain a good staffing level;
- the possible impact of decommissioning on the units that remain in operation.

For point (2), article 17 of the GRR-2001 fixes the different elements that should be part of the dismantling licence application. Priority chapters of the preliminary dismantling safety report have been identified. First exchanges already took place for Doel 3. For the most part, these exchanges concerned the status of the SSCs of the primary circuit during the Post Operational Phase.

I.C.3. Licensee's action plans

a) Safety Culture Action Plan (2015-2019)

During the second quarter of 2015 several non-compliances with the technical specifications were reported at the Tihange nuclear power plant.

In July 2015 the FANC issued a formal letter to the NPP's management highlighting the importance of rigorous compliance with technical specifications and asking for prompt actions to correct the situation. Nevertheless, additional incidents were reported with indications of non-compliance with technical specifications. Consequently, the FANC initiated enforcement measures in August 2015 and reported the incidents to the public prosecutor. The FANC also asked ENGIE Electrabel to develop an action plan aiming at a drastic change in the safety culture of all employees at the Tihange NPP.

ENGIE Electrabel worked on a long-term action plan called "Rigueur & Responsabilité" (Rigor & Responsibility). A first version was submitted to the FANC in January 2016. This plan was updated in April 2016 to take into account the results of internal workshops held with the employees, who were invited to participate directly in this improvement process.

In the meantime, the FANC asked the Electrabel Corporate Management and the other nuclear power plant of Doel to analyse the situation considering the feedback from Tihange and to define action plans in order to improve the safety culture as appropriate.

Finally, ENGIE Electrabel developed an exhaustive Nuclear Safety Culture improvement action plan (the CORE-action plan), with actions for as well the NPP of Tihange and Doel as for the Corporate. Actions were developed in the following areas;

- Leadership;
- Processes & organisation;
- Procedures, rules and IT-tools;
- Social relationship;
- Contractor management;
- Conformity with the technical specifications;
- Training and competence management;
- Operating experience;
- Oversight and monitoring.

The intermediate results and performance improvements were followed up and presented periodically to the regulatory body. Early 2019 all actions were completed, and the 'CORE-plan' was officially closed in agreement with the regulatory body, considering the progress and results achieved. Most of the actions have been integrated in the operational practices and processes and have become standing orders.

Notwithstanding that all actions are closed, the need for further improvement has not disappeared. Meanwhile, new actions plans are launched on fleet, site as well as department level, for instance:

- Every two years, a Nuclear Safety Culture Survey is executed. The first survey was organized in 2017 for all ENGIE Electrabel nuclear staff. The second survey was organized in 2019 and included also the main contractors.
- The results of the survey are used as one of the inputs to define for each team the yearly Nuclear Safety Culture objectives and leadership objectives. The realization of these team-objectives is followed up on site and corporate level.
- In Tihange, Safety Days are organized, to increase the Nuclear Safety Culture awareness and to work around specific Nuclear Safety Culture topics with the complete staff.
- Different 'Coaching in the field', training and mentoring programs are set up and implemented.

The regulatory body will continue to monitor the effectiveness of the action plans.

b) Completion of the Stress Tests Action plan "BEST"

As member of the European Union, Belgium participated in the "Stress Tests" programme initiated by the European Commission after the Fukushima-Daiichi accident. The main milestones of the "Stress Tests" programme developed by ENSREG are listed below:

- Technical definition of the "Stress Tests" by WENRA: May 2011;
- Stress Tests report by the licensee: October 2011;
- National Stress Test report: December 2011;
- Peer review organized by ENSREG of the Stress Tests report: April 2012;
- ENSREG action plan: August 2012;
- Publication of the National action plans: December 2012.

The various reports that have been issued by or for Belgium are available on the following ENSREG website : http://www.ensreg.eu/EU-Stress-Tests/Country-Specific-Reports/EU-Member-States/Belgium (in English) and on the FANC website : https://fanc.fgov.be/nl/informatiedossiers/kerncentrales-belgie/nucleaire-stresstests/verslagen (in Dutch and French).

As a result of the Stress Tests, the ENSREG action plan and peer review and the findings of the extraordinary meeting of the CNS in 2012, a Belgian national Action Plan (called "BEST") was issued in December 2012. More than 300 individual actions have been identified. An overview of the action plan is given in Appendix 6.

The current status (end 2018) of the Belgian National Action plan and other related reports are available on the same FANC web page (in English).

By the end of 2018, ENGIE Electrabel finalized more than 99% (i.e. 362/365 actions) of the stress-tests action plan. Two additional assessments and the construction of a new emergency response facility (backup to the current site operation center) in Tihange should be finalized in 2019.

Since 2011, the sites of Doel and Tihange have witnessed several main achievements: reinforcement of structures, systems and components to face severe earthquakes, construction of protections against flooding and additional mobile means, such as mobile pumps and mobile diesels. Both sites are now adequately protected against natural hazards, such as flooding and earthquakes.

By the end of 2017, the strategy for complete station black-out and for loss of the ultimate heat sink is well-defined on both sites and the related works were finalized.

The construction of filtered venting systems on all reactor buildings at Doel and Tihange were finalized in 2017 (except for Doel 1 and Doel 2, where filtered venting systems belong to the LTO action plan and are scheduled to be operational in 2020).

Figure 3: Filtered containment venting system of Tihange 3

The sites are now protected against external hazards and prepared against Complete Station Black-out (CSBO) and Loss of Ultimate heat Sink (LUHS) events.

However, the workload remains important for the Regulatory body that still has to approve and confirm the closure of 25% of the global action plan (status end 2018). The objective for 2019 is to finalize the stress-tests action plan, both at the licensee and at the regulatory body side.

c) Long Term Operation of Tihange 1, Doel 1 & 2 Action plan

ENGIE Electrabel established action plans both for Tihange 1 and for Doel 1 & 2, which were assessed and approved by the FANC. The first part of these action plans was completed before the first restart of the reactors after the initially foreseen legal shutdown dates. The second part of these actions plans consisted of additional modifications related to ageing and more significant design improvements. The FANC made use of article 13 of the GRR-2001 (the "General Regulations regarding the protection of the public, the workers and the environment against the hazards of ionizing radiation") to propose licence amendments to enforce these action plans.

The execution of the Tihange 1 action plan is on track. However, the remaining actions, which are planned to be executed during a long outage planned from December 2019 until June 2020, are challenging. The main challenge is the commissioning of the "SUR-E = Système d'Ultime Repli Etendu" or "Ultimate Extended Backup System". This SUR-E is an important design improvement and is designed to be an independent backup system that can bring the reactor to a safe cold shutdown state. It includes the necessary instrumentation and control systems as well as independent power supply systems. An important event, linked to the execution of the action plan, was the jet-grouting incident in September 2016, detailed in section I.C.4.a).

The execution of the Doel 1 & 2 action plan is also in progress with the remaining actions to be executed during a long outage planned from October 2019 until April 2020.

The outages of 2018 were scheduled for about 3 months, but eventually the outages of the units Doel 1 and 2, started in May 2018, were extended until the beginning of February 2019 (Doel 2) and March 2019 (Doel 1). This delay was caused on one side by the different actions linked to a primary leak (UPI lines) that appeared end April 2018 at Doel 1 and that led to an early shutdown of the unit. The second major cause of the delay was an underestimation of the workload for the implementation of the LTO action plan and the execution of the associated requalification program of the new and modified equipment.

d) Fire safety improvement plan

As mentioned under I.C.5.b) an integrated fire safety improvement plan, which combines the actions identified through the Fire Hazard Analysis (FHA) and the Fire PSA, is ongoing and will be implemented by 2020. This action plan includes hardware improvements such as installing additional fire detection, fire extinguishers and sprinklers, improving physical separation in certain buildings, an additional firefighting pumping station, coating and rerouting of cables and procedure and work process improvements.

e) WENRA 2014 action plan

In parallel to the development of the proposal of the Royal Decree (see above section I.C.1 - Projects in development) the FANC and Bel V also started a gap analysis, assessing the implementation of the WENRA Reference Levels 2014 in the NPPs. This gap analysis has led to an action plan, which has been discussed with ENGIE Electrabel for implementation.

The main activities that have been started by ENGIE Electrabel in this frame cover amongst others the following topics:

- SRL Issue E: Design Basis Envelope for Existing Reactors
  - Develop the list of Postulated Initiating Events (PIE) for Spent Fuel Pools (SFP);
  - Perform SFP PIEs Analysis;
  - Siphon Breakers analysis in reactor building pools;
- SRL Issue F: Design Extension of Existing Reactors:
  - Develop the lists of Design Extension Conditions (DEC) A/B;
  - Develop governance on Mitigation Strategy for the Belgian NPPs;
  - Perform DEC A/B studies including Survivability Assessment of I&C in DEC B;
  - Design and implement a cavity pit injection system (Tihange units);
  - Design and implement an alternative spray system for the reactor building (Tihange units);
- SRL Issue T: Natural Hazards:
  - Identification and screening of natural hazards including credible combinations;
  - Extended external flooding analysis in DEC;
  - Definition of Maximum Credible Hazard in DEC i.e. "EL2/MCE" for Seism;
- SRL Issue O: Probabilistic Safety Analysis:
  - Spent Fuel Pool PSA Internal Events, Fires and Floods;
  - Seismic PSA for reactors and Spent Fuel Pools.

This list is non-exhaustive. The detailed Action Plan, which aims to fully comply with the future regulation change based on the WENRA RLs 2014, is under preparation by ENGIE Electrabel.

Figure 4 shows an overview of the action plan.

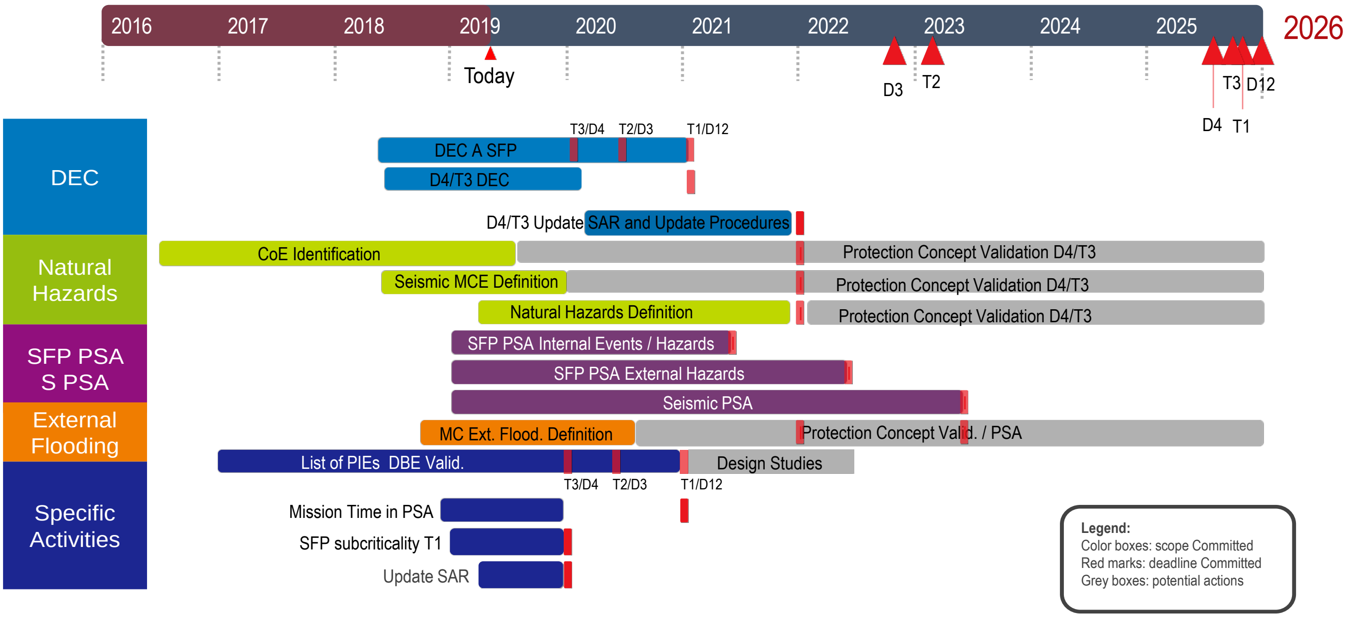

Figure 4: WENRA 2014 Action plan

I.C.4. Main safety events 2016-2019

a) Jet Grouting and soil problems at Tihange 1

In order to create a dry work area for the construction of an underground gallery in the framework of the "Long Term Operation of Tihange 1" project, ENGIE Electrabel was performing jet grouting activities close to an existing building ("W building" housing, among others the steam generator auxiliary feedwater turbo pump).

On September 7th, 2016, ENGIE Electrabel observed several damages at the ground floor of the W building: cracks and displacements of the ground floor and foundation slabs supporting the turbo pump, and its piping.

Electrabel decided to bring the unit to safe shutdown, to stop the jet grouting activities and to directly carry out investigations regarding the records from the jet grouting activities, the structural damages, the equipment damages and the characterization of the ground under the W building.

The results of the investigations showed that the event was caused by a progressive rise of pressure in the ground caused by the combination of several non-conformities from the company in charge of the jet grouting activities with a mischaracterization of the soil.

Some preliminary characterization tests of the ground under the W building revealed the presence of a less compacted soil layer located between 6m and 7m depth. Additional investigations of the ground under different buildings of the concerned unit revealed that the ground characteristics of a large zone around the reactor building are not consistent with the ground characterization referred to in the Safety Report of the unit. The soils used in the 70's to refill the foundations of the buildings around the reactor did not fulfil the design technical requirements.

ENGIE Electrabel therefore reinforced the ground directly under the concrete foundation slab that had risen during the incident. After analysis of ENGIE Electrabel and assessment by the regulatory body of the impact of this non-conformity on the seismic resistance of this building, the regulatory body asked ENGIE Electrabel to reinforce the ground under the foundations of this building before considering restart of the reactor. ENGIE Electrabel completed this soil consolidation at the end of April 2017. The analysis of the results, conducted during the first half of May 2017, showed the structural solidity of the building in the event of an earthquake.

Other buildings of Tihange 1 NPP were inspected simultaneously. Soil inspections and assessments concluded that these other buildings did not require soil consolidation and that their capability to withstand the design basis earthquake was confirmed.

The FANC eventually authorized the restart of the Tihange 1 unit on May 15th, 2017.

b) *Extended shutdown of NPPs for concrete repair*

Inspections during the planned outage of Doel 3 in October 2017 discovered concrete degradation on the bottom of the bunker building roof plate. These bunker buildings house the "second level" protection systems such as emergency diesel generators and emergency pumps to inject water into the primary circuit and the steam generators, designed specifically to be used in case of external initiating events. This building is designed to withstand the impact of extreme external events such as an airplane crash and this degradation could have impaired this design capability. Following the detection of this degradation, inspections were also carried out on the other Belgian units having an equivalent design, i.e. Tihange 3, Tihange 2 and Doel 4. During these inspections, the same type of degradation, however with variable severity, was also found.

The degradation results from a specific function of this part of the bunker buildings. In case steam flow from the steam generators cannot be discharged into the main condenser this steam flow is discharged through the steam generator relief valves and safety valves into the rooms below these roof plates, which are protecting them from the external events, and further to the atmosphere. This steam flow exposing the bottom of the roof plates to high temperature and humidity is the cause of the degradation.

While uncovering the degraded parts of the concrete of the bunker building roof plates, anomalies were found in the reinforcement of the concrete, more precisely mispositioning of some of these reinforcements during the initial construction of the buildings on one hand and corrosion of the lower reinforcement on the other hand.

The extent of the issues discovered led to the need to reconfirm the ability of these buildings to withstand to the initiating events postulated at the initial design, and particularly to an air plane crash.

In October 2018 the FANC decided to classify these anomalies as an overall INES 1 event for the concerned units: Doel 3, Doel 4, Tihange 2 and Tihange 3.

On the ENGIE Electrabel side, the Independent Nuclear Safety Oversight (INSO) department, supported by external independent experts in civil engineering, challenged the inspections, the repairs and the calculations performed by the engineering department of the operating organization.

FANC and its technical subsidiary Bel V closely followed all repair works, both through examination and evaluation of documents, quality plans and test results, as through inspections on site with support of civil works experts.

<u>Doel 3:</u>

At Doel 3, the degradation of the existing roof plate has since been repaired and a new additional roof plate was built. These works were conducted under supervision of the INSO and of the FANC and Bel V. On the basis of these works and calculations, the initial air plane crash resistance has been restored and, after the positive advice from the INSO and review by Bel V, the FANC approved restart of the reactor in July 2018.

<u>Tihange 3:</u>

At Tihange 3, less severe degradation was discovered during the planned outage in April 2018. However, when uncovering the degraded parts of the concrete, anomalies were found in the positioning of the steel reinforcements. At the end of December 2018, the repair works of the bunker roof plate had progressed sufficiently and, after the positive advice from the INSO and review by Bel V, the FANC authorized restart of the unit. In order to further increase the safety margins, ENGIE Electrabel has committed itself to construct an additional roof plate during the planned outage in the summer of 2020.

<u>Tihange 2:</u>

Inspections and subsequent repair work started in the planned outage of July 2018. The works and calculations necessary to demonstrate that the air plane crash resistance has been restored have been performed under supervision of the INSO, FANC and its technical subsidiary Bel V. An additional roof plate has been constructed to further increase the safety margins. FANC has approved restart of the reactor in June 2019.

<u>Doel 4:</u>

Inspections and subsequent repair work started in August 2018. Degradation as well as anomalies in the reinforcements were less severe and it could be confirmed that the initial air plane crash resistance was restored after repair works, without an additional roof plate. The reactor was restarted in December 2018, after positive advice by the INSO, review by Bel V and approval by the FANC.

c) *Leak in an Upper Plenum Injection line of Doel 1 NPP*

In April 2018, during full power operation of the Doel 1 nuclear power plant, a primary leak of around 4 to 5 l/min occurred and the reactor was consequently stopped and brought to cold shutdown. Investigations showed the leak to be situated in a part of one of the Upper Plenum Injection (UPI) lines, non-isolable from the reactor.

The 4" Stainless Steel 316 UPI lines are part of the Safety Injection system and are typical for the Westinghouse 2-loop design. They enable safety injection to be applied directly in the upper plenum of the reactor vessel, in addition to cold leg injection.

After the leak location was found in the UPI-A line, an extensive non-destructive inspection campaign was started on all UPI-lines (A and B) of both Doel 1 and Doel 2. These inspections revealed that the corresponding UPI-A line of Doel 2 also showed similar degradation in the same area. As a result, all pipe sections with reportable indications have been cut and replaced.

The inspections and repairs were performed in difficult technical and logistical circumstances (difficult accessibility, lack of space and high radiation dose) as the affected UPI pipelines are located in the cavity near the reactor vessel.

The removed pipes, containing the leak or indications, were examined in two independent laboratories. All examinations identified low-stress high-cycle fatigue to be the damage mechanism, the crack initiation and propagation showing to be a slow, multi-annual process.

The root cause analysis concluded that thermal fatigue is responsible for the observed cracking: temperature fluctuations in the quasi-horizontal stagnant branch, perturbed by instabilities, have led to cyclic thermal stresses.

Exploratory calculations show that thermal stress cycles in the UPI-B lines, which are shorter and have a different geometry, appear to be more limited, explaining the absence of degradation in these lines.

An extensive inspection of all other possibly susceptible non-isolable reactor coolant circuit branch lines, going beyond the recommendations of applicable EPRI guideline, was performed and revealed no reportable indications.

A comprehensive temperature, displacement and vibration monitoring has been installed on the UPI-lines of both units, in order to guarantee a close follow-up of the thermal and mechanical behaviour of the lines during all operational modes. Re-inspection of the areas of concern is foreseen during the next outages.

The understanding of the initiation and propagation of the damage phenomenon, the successful repair and the risk mitigating measures taken, allowed ENGIE Electrabel to introduce a safety file stating that both units can be operated in a safe manner and justifying start up. This safety file was analysed and approved by the regulatory body.

Based on the understanding of the damage phenomenon, the successful repair and all risk mitigating measures taken, the FANC authorized Doel 2 and Doel 1 to resume operation in January 2019 and in February 2019 respectively.

I.C.5. Other developments

a) *Flaw indications in reactor pressure vessel of Doel 3 and Tihange 2*

During the 2012 outages of the Doel 3 and Tihange 2 nuclear reactors, specific ultrasonic in-service inspections (UT) revealed the presence of a large number of quasi-laminar flaw indications in the lower and upper core shells of both RPVs. It was decided that both reactors would remain shut down until ENGIE Electrabel could demonstrate to the FANC that the newly discovered flaw indications did not affect the safety of both reactors.

After several safety evaluations conducted both by ENGIE Electrabel and independently by the regulatory body, the FANC authorized the Doel 3 and Tihange 2 reactor units to resume operation until they reach the age of 40 years. After an extended shutdown of 20 months, Tihange 2 and Doel 3 units were put back into operation in December 2015 and January 2016 respectively.

The reports have been published on the FANC web site: https://afcn.fgov.be/fr/dossiers-dinformation/centrales-nucleaires-en-belgique/actualite/indications-de-defauts-dans-les

The FANC required ENGIE Electrabel to perform follow-up UT-inspections using the qualified procedure on the RPV core shells at the end of the next cycle of Doel 3 and Tihange 2, and thereafter at least every three years.

Consequently, a new UT inspection of the RPV of Doel 3 was done in October 2016 and an inspection of the RPV of Tihange 2 was done in April 2017. Both inspections used the same qualified method as the one used in 2014. The results of those inspections showed that there was no evolution in the population of the indications. Some indications, close to the rejection thresholds, appeared during the new inspection but it was shown that they were already present during the inspection of 2014 and that the fluctuation in the reporting was due to a measurement threshold effect; other indications followed the inverse path: they were reported in 2014 but were below the rejection threshold in 2016/2017. For conservative reasons, it was decided to take into consideration in the Structural Integrity Assessment (SIA) all the flakes once reported and never removing them of the SIA analysis. The FANC has validated the conclusion of ENGIE Electrabel that the population of the indications is stable, does not evolve in any sense and that the operation of the plants may be pursued in accordance with the conclusions of the Safety Case of 2015.

The reports have been published on the FANC web site.

All other Belgian RPVs (of Doel 1, Doel 2, Doel 4, Tihange 1 and Tihange 3) have been screened for hydrogen flakes. No indication of hydrogen flakes was reported in any plant.

b) Development of Probabilistic Safety Assessments (PSA)

Updates of Level 1 and Level 2 Internal Events PSA models have been completed for Doel 3 and Tihange 2 and are ongoing for all other units and should be finished by 2020. These updates take into account a selection of modelling improvements coming from the Periodic Safety Review, as well as plant data and configuration for the plant status at the end of 2017. Mobile and portable equipment that has been installed following the stress tests, is taken into account in the PSA modelling.

The results of Level 1 and Level 2 Internal Events PSA are used to assess whether the plant risk is well balanced, and where appropriate, to identify further improvements to plant operation.

Level 1 Fire and Flooding PSA models have been established for all units in order to fulfil the requirements of the WENRA Reference Levels (2008), which have been translated into Belgian law under the Royal Decree of 30 November 2011. A fire safety improvement action plan is ongoing, which combines the actions identified through the Fire Hazard Analysis (FHA) and the Fire PSA, and will be implemented by 2020. No actions resulted from the Flooding PSA.

Level 2 Fire and Flooding PSA models have been elaborated for one representative unit. Some recommendations have resulted from the Level 2 Fire PSA.

ENGIE Electrabel uses PSA on a continuous basis as an additional tool to support nuclear safety decisions. It is for example provided in the utility procedures that PSA has to be used to assess plant modifications, procedural modifications and Technical Specifications modifications. It should be highlighted that PSA is nevertheless not a motive for changes in Technical Specifications.

Important new developments of PSA are done in the framework of the WENRA Reference Level 2014 action plan as described in section I.C.3.e).

c) Periodic Safety Reviews

The operators of nuclear power plant(s) are obliged under the Royal Decree of 31 November 2011 and the provisions of their licence to conduct a Periodic Safety Review (PSR) every 10 years.

Since 2007 the FANC has required that plant operators perform the PSR following a methodology based on the 14 Safety Factors described in the IAEA Safety Guides NS-G-2.10 and SSG-25. The regulatory body oversees this process by reviewing the analysis and approving the resulting action plan.

This process has already been applied successfully for the third PSR of the Doel 3 & Tihange 2 units (2012 & 2013 respectively), the third PSR of the Doel 4 & Tihange 3 units (2015), and the fourth PSR for the Long Term Operation of the Doel 12 & Tihange 1 units (2015). The PSR action plan has been implemented for Doel 3 & Tihange 2 and has largely been implemented for the other units.

The next PSR is being prepared in the framework of final plant shutdown before dismantling and decommissioning. Proactively Long Term Operation instead of final shutdown is being considered for some units, depending on potential upcoming Belgian governmental decisions on future energy policy.

d) INES Events

In 2016, 2017 and 2018, ENGIE Electrabel reported respectively 7, 2 and 9 events classified as level 1 on INES. There was no incident classified as level 2 of higher on INES during this period.

For research reactors, the number of events classified as level 1 on INES that was reported during the same period was respectively 0, 2 and 0.

I.C.6. Peer reviews

Peer reviews are regularly organized in Belgium. A list of previous missions that took place during the period 2009-2016 can be found in the previous edition (2016) of this report. Recent or planned missions are listed below:

- In December 2016, the SALTO follow-up mission was organized at Tihange 1.
- A SALTO mission was organized at Doel 1 & 2 NPPs from 14 to 23 February 2017. The report is available on the FANC web site: https://afcn.fgov.be/fr/system/files/salto-rapport_doel_1_en_2.pdf. The follow-up mission took place in June 2019: https://www.iaea.org/newscenter/pressreleases/iaea-concludes-long-term-operational-safety-review-at-belgiums-doel-nuclear-power-plant.
- At the initiative of the FANC, Belgium hosted an IRRS follow-up mission form 27 November to 4 December 2017. The report is available on the FANC web site : https://afcn.fgov.be/fr/system/files/irrs-belgium-2017-follow-up-final-mission-report.pdf .
- Belgium participated in the first "Topical Peer Review" (TPR), as required by the European Directive 2014/87/EURATOM. Findings and conclusions of this peer review are summarized in section d) below.
- The first ever IAEA peer review mission on ageing management of research reactor was organized for BR2 in November 2017.
- An IPPAS follow-up mission took place in June 2019, after the cut-off date for this report.

According to the European Directives 2009/71/EURATOM and 2014/87/EURATOM, Belgium has to organize a new IRRS mission before end 2023

Belgian experts also regularly participate in IRRS and in other international peer review missions such as OSART missions.

a) SALTO Follow-up mission in Tihange 1 unit in 2016

In December 2016, the SALTO follow-up mission noted good progress since the SALTO mission of 2015:

- Two of the three Recommendations were resolved, and sufficient progress was made on the third;
- Six of the seven Suggestions were resolved, and sufficient progress was made on the seventh.

b) SALTO mission in Doel 1 & 2 units in 2017

A SALTO mission took place at Doel 1 & 2 in February 2017.

The IAEA team conducting the mission found the plant staff to be professional, open and very receptive to suggestions for improvement. Walkdowns showed that the plant was in good condition. The IAEA team concluded that plant management is committed to improving plant preparedness for LTO. The team recognized that the plant approach to and preparatory work for safe LTO follow the IAEA Safety Standards and international practices.

Areas for improvement in order to reach the level of international good practice were also identified. The team identified the following issues as being the most significant ones:

- The plant should ensure that all required systems, structures and components are included in the scope of ageing management during the LTO period;
- The plant should ensure consistency and completeness of data for structures and components over the LTO period;
- The plant should complete the review and update of the ageing management programmes for civil structures and components for the LTO.

In addition, the team noted 3 good practices and performance:

- integrated risk management for LTO at various levels;

- a comprehensive scoping methodology for selecting the systems, structures and components for the analysis regarding ageing during the ten-year LTO period;
- measures to address staff turnover to ensure that knowledge is not lost when staff members leave.

A follow-up mission took place in June 2019 and concluded that sufficient progress has been made and that plant management had:

- Improved organizational arrangements to support ageing management for the period of long term operation (LTO);
- Updated the Safety Analysis Report with ageing management and LTO assessment results; and
- Enhanced competence and knowledge management for plant personnel involved in ageing management.

The team noted also that further work is necessary to ensure that all required structures and components are included in the scope of ageing management during the LTO period. The official report will be available in the second part of 2019.

c) IRRS Follow-Up Mission

Belgium received an IRRS initial mission from December 1st until December 13th, 2013. This mission was a full scope mission and covered all regulatory activities performed by the FANC and Bel V. The full report of the mission can be found on the FANC website (IRRS Mission Belgium, 2013).

Soon after the IRRS mission, the Belgian regulatory body drew up an action plan to address the recommendations and suggestions. This action plan not only addressed the recommendations and suggestions, but included also the self-assessment and its corresponding action plan in preparation of the IRRS-Mission, the FANC's strategic plan, taking into account the upcoming challenges such as the phase-out of nuclear energy and the implementation of the European BSS and specific demands from the operational departments of the FANC.

The regulatory body received a follow-up mission from November 27th till December 5th, 2017. The report of this mission can be found on the FANC website (IRRS Follow Up Mission Belgium, 2017). The IRRS team concluded that the recommendations and suggestions detailed in the 2013 IRRS mission report have been given due consideration. Notable achievements include e.g.

- New and amended proposals for regulation and other arrangements clarifying roles, responsibilities and authorities within the regulatory framework, including confirmation of the independence of the Regulatory Body in its reporting lines from those within government responsible for the promotion of nuclear energy and reissuing the transport regulations;
- The amended FANC law has clarified the roles and responsibilities of the regulatory body which has led to closer interaction between FANC and Bel V;
- Establishing a project to systematically prepare the regulatory body for the future challenges of regulating an increase in decommissioning activities and radioactive waste safety;
- An effective tool developed by Bel V to assist in the review and assessment of safety related modifications through a clearly defined graded approach to safety;

From the 31 Recommendations and 24 Suggestions of the original mission, 2 Recommendations and 2 Suggestions remained open. All other Recommendations and Suggestions were either "Closed" (28 out of 55) or "Closed on the basis of progress made and confidence in effective completion" (23 out of 55). The IRRS Follow Up mission identified 3 new Suggestions and 2 Good Practices.

The Belgian Regulatory Body developed an action plan covering the open issues as well as the issues that were "Closed on the basis of progress made and confidence in effective completion". The main topics that required some further attention and work were:

- Publication of National policy and strategy for nuclear and radiation safety;
- Full implementation of the management system, including elements such as implementing a clear decision process, competence and knowledge management;
- Finalisation and publication of several amended regulations and related internal guidance documents;

At the date of publication of this report, 75% of the actions have been finalised.

d) The first European Topical peer review on ageing management

In 2014, the European Union (EU) Council adopted directive 2014/87/EURATOM amending the 2009 Nuclear Safety Directive to incorporate lessons learned following the accident at the Fukushima Daiichi nuclear power plant in 2011. Recognizing the importance of peer review in delivering continuous improvement to nuclear safety, the revised Nuclear Safety Directive introduced a European system of Topical Peer Review (TPR) starting in 2017 and every six years thereafter. The purpose is to provide a mechanism for EU Member States to examine topics of strategic importance to nuclear safety, to exchange experience and to identify opportunities to strengthen nuclear safety. The European Nuclear Safety Regulators Group (ENSREG) identified in July 2015 ageing management of nuclear power plants as the topic for the first Topical Peer Review.

ENSREG informed the WENRA association, who prepared the Technical specifications.

The review process consisted mainly in three phases:

1) In the first phase national self-assessments were conducted against the WENRA Technical Specification
2) In May 2018, ENSREG organized a one-week workshop to discuss the results of the self-assessments, the questions and comments on the National Assessment Reports, as well as the replies to the questions, with a goal to identify and discuss both generic and country-specific findings on Ageing Management Programmes.
3) In the third and final phase of the Topical Peer Review, a Topical Peer Review Report and country specific findings have been compiled to provide input for national action plans and ENSREG work.

The main conclusions for Belgium identified during the workshop are listed below:

For the BR2 Research Reactor:

- BR2 is considered as having the most advanced ageing management program for research reactors in Europe.
- There were no negative findings.
- All positive findings of the Topical Peer Review were allocated to BR2.
- Two specific 'Good Practices' were identified:
    - The organisation of a SALTO-like Mission for Research Reactor (November 2017, see point e) below);
    - The structured Ageing Management Program for the Reactor Vessel.

For the Belgian NPPs:

- Good ageing management program in comparison to average European level.
- There were no specific negative findings. Only generic 'Areas for Improvement' or challenges valid for all NPPs in Europe.
- One Good Practice was identified: The use of reconstruction specimens for strengthening irradiation embrittlement monitoring.
- 7 Good Performances were identified.
- Main challenges to address were:
    - Improving the KPIs dedicated to ageing management;
    - Monitoring of non-accessible areas of the containment;
    - Ageing Management Program for long outages.

The full reports are available on the ENSREG web site: http://ensreg.eu/eu-level-reports

e) The first IAEA peer review mission on Ageing Management of Research Reactors

The IAEA Research Reactor Safety Section introduced a new peer review service on ageing management of research reactors. The methodology is based on the SALTO reviews for nuclear power plants. A review of the BR2 research reactor was conducted in November 2017 during 6 working days by a team of 6 experts. Conclusions and recommendations of this mission are in line with those from the European Topical Peer Review.

I.C.7. Communication with the Public

The **FANC** is in charge of disseminating objective and neutral information about radiation risks, as stipulated in article 26 of the law of 15 April 1994.

Interested parties that are informed by the FANC include:

- the general public and the media:
  - the FANC and Bel V have their own web sites. The FANC web site allows the general public to contact and ask questions to the FANC;
  - the media are informed by the FANC management and the FANC communication office. Important events give rise to press releases and conferences;
  - laws and regulations are published in the Belgian official journal ("Belgisch Staatsblad-Moniteur Belge"), as well as notification of decisions (licensing of class I facilities, recognition of experts in health physics …). A consolidated version of the regulations is available on the FANC web site (http://www.jurion.fanc.fgov.be);
  - the general public is consulted ("public inquiry") in the frame of the licensing process of high risk facilities (Class I and some Class II), with the possibility to attend information meetings organized by the FANC;
- the supervising Minister and the Parliament through:
  - the answers proposed by the FANC to questions addressed by Members of Parliament to the minister;
  - the government commissioner who attends the meetings of the Board of Administrators;
  - the annual report submitted to Parliament;
  - the follow-up by the parliamentary commission on Home Affairs and the sub-commission on Nuclear Safety;
- the licensees: several formal and informal communication mechanisms are in place, including regular "Stakeholder's Meetings";
- other interested parties: The GRR-2001 foresees that other parties are notified of the FANC decisions: For example, article 6.8 prescribes notification of the granted licences to local authorities, to some federal administrations, to the civil protection administration, to ONDRAF/NIRAS, to the European commission and other European countries when relevant.

The government and the public are also informed by the annual report of the FANC. This report is published on the FANC web site, together with the Bel V annual report.

The main communication tool of the FANC is its web site www.fanc.fgov.be. Several reports, information files about the radiation risk of different facilities and activities or about particular subjects are available. News Flashes are also regularly published on the web site.

INES (International Nuclear and Radiological Event Scale) has been used in Belgium for almost 30 years now.

Currently, a technical regulation of the FANC of 5 July 2019 determines the criteria and modalities for notification of events and the use of INES. This technical regulation replaces a convention between the licensees, the FANC and Bel V. As the convention did before, the technical regulation stipulates in which circumstances and how INES is to be used. The licensee has to perform the INES-analysis according to the latest INES manual, and this level has to be approved by Bel V and the FANC. Depending on the INES-level, a specific notice is issued. For events of level 1 or higher, the FANC publishes a short notice on its website (https://fanc.fgov.be/nl/noodsituaties/ines-schaal/gebeurtenissen-belgie-ingedeeld-op-de-ines-schaal-van-de-laatste-12). For events of level 2 or higher, besides the notice on the website of the FANC, the licensee has to issue a press release about the event and the INES National Officer notifies the IAEA.

Finally, since 2012, the radioactive releases of all Belgian nuclear and waste facilities with their calculated radiological impact are published annually on the FANC web site : https://afcn.fgov.be/fr/dossiers-dinformation/radioactivite-dans-lenvironnement/surveillance-radiologique-du-territoire-0 (in French).

Information about the Periodic Safety Reviews is given on the following page : https://afcn.fgov.be/fr/dossiers-dinformation/centrales-nucleaires-en-belgique/surete/revisions-decennales

After each review meeting of the CNS, the FANC publishes on its web site:

- The National Report;
- Questions and answers on the national report;
- The national presentation at the Review Meeting;
- The Rapporteur's report for Belgium.

This information for the 7th review meeting can be found (in French and in Dutch) on the following web page : https://afcn.fgov.be/fr/lafcn/relations-internationales/conventions-et-traites-internationaux/convention-sur-la-surete-0

The results of the measurements performed by the **TELERAD** network (See article 16 of the CNS, section II.L.2.b) are available on the FANC web site as well. This provides the possibility to all interested parties to have an online overview of the measured radioactivity on the Belgian territory.

All events related to nuclear activities and radiation are rated on the INES-scale (International Nuclear and Radiological Event Scale).

ENGIE Electrabel has taken several initiatives to inform the general public, in particular in the vicinity of the NPPs:

(1) Communication policy

Doel and Tihange NPP's external communications are aimed at:

- Informing the public about their nuclear activities;
- Communicating its commitment to environmental protection and nuclear safety to the public at large;
- Increasing the public acceptance of the power plant.

The Belgian power plants pursue a pro-active and open communication policy in order to achieve these goals.

(2) Website and Social Media

Both Doel and Tihange NPP have a specific dedicated webpage on the ENGIE-website. On this webpage key figures on the plants can be found, as well as information on current big projects, press releases, publications, currently relevant information, … In case of specific subjects and questions on social media, the social media channels of ENGIE are also being used to give information on nuclear topics.

https://corporate.engie-electrabel.be/local-player/nuclear-3/

https://corporate.engie-electrabel.be/nl/lokaal-producent/kernenergie/doel/

https://corporate.engie-electrabel.be/fr/producteur-local/nucleaire/tihange/

(3) Information magazine

The free bi-yearly information magazines 'Doelbewust' and 'Tihange Contact' are distributed freely to respectively 77,000 and 47,000 people living in the vicinity of the power plants.

(4) Consultative bodies

The 'Klankbordraad' and 'Comité de Riverains" are consultative bodies set up to reinforce the relations between the power plants and local residents (people living or working in the area). This consultative body is made up of members from various sectors: education, environmental organizations, social sector, etc. It meets several times a year. The members are kept informed of current news regarding the power plants on a regular basis.

(5) Environmental report

Every year the Belgian power plants distribute an environmental report in which the environmental results and objectives are being explained to the public.

https://corporate.engie-electrabel.be/local-player/nuclear-3/environment/

(6) Social initiatives

The power plants support numerous initiatives in the neighboring municipalities.

(7) Guided tours for visitors

For specific stakeholders, visits to the power plants are still being organized. Due to legal access regulations and restrictions, visits are no longer possible for large groups.

(8) Relations with the media

Journalists have a Single Point of Contact.

(9) Information campaign of the Nuclear Forum

The Nuclear Forum was set up in 1972 and represents the majority of Belgian companies and institutions which devote efforts to the civil application of nuclear energy. ENGIE Electrabel plays an important role in this Forum. The Nuclear Forum launches public awareness-raising campaigns on nuclear energy in Belgium.

I.C.8. R&D Programmes in safety

The **Belgian Regulatory Body** (FANC and Bel V) is active in many R&D activities. Such R&D activities are performed to allow the Regulatory Body to take independent and informed safety positions and decisions, based on advanced and detailed scientific information, in most of the technical domains relevant for safety. Since the last report of 2016, the main efforts in the area of R&D for nuclear safety are given below.

Thermal hydraulic accident analysis: Bel V has since a long time developed the capabilities to perform independent accident analyses of Belgian nuclear installations by means of the CATHARE (mainly) and the RELAP5-3D codes. Bel V also continues its important effort to participate in projects managed by OECD/NEA such as ATLAS and PKL, including the active contribution to analytical working group activities. Bel V also participates to the IRSN's DENOPI project to better understand the behaviour of SFP in case of loss of cooling or loss of coolant accidents, and to the R2CA Horizon2020 project sponsored by the European Commission about the Reduction of Radiological Consequences of design basis and design extension Accidents.

Fuel behaviour: Bel V continues its participation to the OECD/NEA Halden Reactor Project until the end of the project in 2020, with the objective to get information of post irradiation examinations of already irradiated material.

Severe Accidents Progression: Bel V holds the Cooperative Severe Accident Research Program (CSARP) agreement with USNRC for Belgium. In this context Bel V has access to the MELCOR code and provides access to the code to other Belgian organizations such as Tractebel ENGIE and SCK•CEN. With the objective of strengthening the capabilities of independent severe accident safety assessment, Bel V developed a database of MELCOR input decks for accident analyses, which covers some Belgian nuclear installations, experimental facilities and other NPPs.

In support of Bel V's activities related to the hydrogen and fission-product-related issues in a containment in severe accident conditions, Bel V participates to the OECD/NEA BIP-3 and THAI-3 projects. Active participation to the analytical activities by means of Computational Fluid Dynamics (CFD) code simulations with the support of the von Karman Institute for Fluid Dynamics is also ongoing for the THAI-3 project.

Bel V participates actively to the MUSA Horizon2020 project sponsored by the European Commission about the Management and Uncertainties of Severe Accidents, and as observer to the IVMR project about In Vessel Melt Retention in the same framework.

Fire protection: Bel V continues its involvement in the PRISME project series and FIRE databases of OECD/NEA, by participating to benchmark activities and providing information from Belgian fire events.

Mechanical Safety: Bel V is co-lead (together with IRSN) in an international project in the framework of the Working Group on Integrity and Ageing of Components and Structures of the OECD, which aims at performing a benchmark of the extended Finite Element Method amongst different countries / codes.

Bel V is participating with IRSN to new experiments conducted at CEA, which objective is to analyse the effect of biaxiality on the stress state and fracture mechanics behaviour of steel containing hydrogen flakes.

Ageing: Bel V participates to the ODOBA (Observatory of the durability of reinforced concrete structures) experimental project to study concrete pathologies and their consequences for nuclear structures (like reactor containments and waste disposal facilities) within the context of extending the service life of nuclear facilities, so as to assess on their durability.

Waste and decommissioning: FANC and Bel V make a considerable investment in obtaining expertise in waste management related issues, required for the review by the Regulatory Body of future safety assessments for a geological disposal of high-level and long-lived radioactive waste.

Bel V actively participates in the Horizon 2020 first European Joint Programming on radioactive waste management and disposal sponsored by the European Commission, named EURAD.Together with the Dutch National Institute for Public Health and the Environment, Bel V developed a methodology for the derivation of surface clearance levels from a controlled area of a nuclear facility called SUDOQU.

Other examples of projects in this field in which FANC and/or Bel V participate are the European SITEX project, the Mont Terri project and the IAEA GEOSAF and HIDRA projects.

Emergency preparedness: In view of strengthening its expertise and competence in emergency preparedness & response, Bel V actively contributes to the Horizon 2020 FASTNET (FAST Nuclear Emergency Tool) project by participating to benchmark exercises with the aim to calculate the source term with the codes PERSAN, developed by IRSN, and RASTEP, developed by Lloyd's Register.

Sponsoring R&D: Bel V continues its effort to sponsor nuclear safety related research with universities and research institutes. These efforts are mainly undertaken by sponsoring doctoral thesis projects or post-PhD positions. The main areas in which projects are sponsored are fire protection, waste management, thermal hydraulic analysis and severe accident progression.

ENGIE Electrabel is also active in the field of R&D, in collaboration with other divisions of the ENGIE Group.

The Group has defined a roadmap with their R&D needs, covering the following areas that are relevant for Electrabel: long term operation, plant retirement, plant safety, operational excellence, flexible operations and grid requirements, fuel reliability, back-end cycle and waste, security and environmental issues. The R&D roadmap is being revised on a periodic basis.

Some of those projects are shortly listed below (this list is not exhaustive) for each field of research:

- Phenomena occurring during transient, incident conditions and accident conditions:
  - Participation in OECD/NEA WGAMA projects (e.g. ROSA, PKL, BEMUSE);
  - Participation in OECD/NEA Working Group on fuel Safety (WGFS);
  - Participation in the Halden Project and IAEA FUMEX fuel rod codes benchmark (high burn-up fuel);
  - Participation to MERCI experiment (reduction of uncertainties of short-time residual power).
- Phenomena during Severe Accidents:
  - Participation in SERENA (steam explosion) and Nugenia;
  - Participation in SARNET2 (uncertainties in severe accidents) and USTA;
  - Participation in BIP1-2-3 (iodine behavior);
  - VERDON program (Fission product behavior during release) part of ISTP (fission products and iodine);
  - Participation to MCCI, CCI, VULCANO and ROSAU (corium concrete interaction and ex-vessel coolability);
  - Air-SFP (spent fuel pool air-ingress scenarios) with MELCOR;
  - IVMR (in vessel melt retention) with a focus on Work Packages CFD use, RPV mechanical resistance and Reactor application (with MELCOR).
- Fuel Behavior:
  - Fuel Benchmark REGAL (Rod-Extremity and Gadolinia AnaLysis);
  - Axial gas flow in irradiated fuel rods (AGAF Project).
- Chemistry:
  - Optimization of H^2 concentration in the primary Circuit.
- Nuclear waste conditioning:
  - Conditioning of low-level radioactive evaporator concentrates;
  - Development of a process for the conditioning of ion exchange resins (REI) in a cement matrix Waste for MEDOC Project.

- Understanding and mitigation of materials ageing:
  - Protection of concrete subject to extreme conditions of T°, pressure and humidity;
  - Participation to the ECRAN project (Concretes carbonatation);
  - Extend and improve the experimental database on the surveillance materials to improve experimental techniques and evaluation procedures to keep them at the state of the art;
  - Improving understanding of Irradiation Assisted Stress Corrosion Cracking (IASCC) and Primary Water Stress Corrosion Cracking (PWSCC);
  - Effect of reactor coolant environment on fatigue life of reactor materials.
  - Extent of accelerated carbonatation in reinforced concrete due to microcracks.

Research agreements are set up with organizations such as the French CEA and SCK•CEN. These research centers work on several projects linked to ENGIE Electrabel R&D.

I.C.9. Major common issues arising from country groups discussions of the 7th review meeting

a) Safety Culture

See Sections I.C.3.a), II.F, and II.H of this report.

b) International Peer Reviews

See Section I.C.6 of this report.

c) Legal Framework and Independence of Regulatory Body

See Sections II.C, II.D.4 and II.D.5 of this report.

d) Financial and human resources

See Section II.D.3 (regulatory body) and II.G (Licensees) of this report.

e) Knowledge management

See Section II.D.1 (regulatory body), II.G.1.e) and II.G.2.b) (Licensees) of this report

f) Supply Chain

The issue regarding the supply chain of components qualified for use in nuclear applications is also pertinent for all Belgian nuclear power plants.

An additional challenge is the existence of specific Belgian qualification rules, requiring additional efforts to be able to use components qualified according to American, French or German rules in the Belgian power plants, combined with the fact that the size of the Belgian market for qualified material is limited.

The ENGIE Electrabel obsolescence management methodology to deal with this issue is based on the IAEA "TOP401 - Technical Obsolescence Program Note." This methodology describes how the typical steps in the process (identification of obsolescence issues, prioritization of obsolescence issues, implementation of solutions, monitoring and trending) are developed at ENGIE Electrabel. The inputs used in the identification phase are amongst others the purchasing process, feedback of the Component Experts, the supplier audit process and System and Component Health reporting. The prioritization strategy uses the following parameters: the available stock, the past consumption rate, the number of installed components, the failure rate, the classification and qualification level. These parameters are used to develop obsolescence item scorecards.

An "equipment qualification and obsolescence" project (EQO), common between ENGIE Electrabel, Tractebel ENGIE and Bel V, has been launched. The project is divided in several working groups, each focusing on a specific solution path. Examples are the use of components qualified in France, the use of commercial grade dedication and the use of 3D printing for reverse engineering.

g) Managing the Safety of Ageing Nuclear Facilities and Plant Life Extension

See Sections I.C.6.a), b) and d) and I.C.3.c) of this report.

h) Emergency Preparedness

See Section I.C.1.a)(2) and II.L of this report.

i) Stakeholder Consultation & Communication

See Section II.C.7 of this report.

I.D. Planned measures to improve safety

In summary, for the **regulatory body (the FANC and Bel V),** the following measures to improve safety are planned for the period 2020-2023:

a) Legal framework improvement:
   - Finalization at short term of the incorporation into Belgian regulations of the WENRA 2014 Safety reference Levels;
   - Finalization at short term of the incorporation into Belgian regulations of remaining requirements of the European Basic Safety Standards (Directive 2013/59/EURATOM);

b) Oversight and completion of the ongoing action plans of ENGIE Electrabel.

c) Preparation, including self-assessment and definition for the next IRRS in Belgium that will have to take place before 2023;

d) Continuation of international bilateral and multi-lateral cooperation activities, namely for supporting development of new standards, e.g. through the IAEA Safety Committees and the WENRA working groups;

e) Ensure that the safety will remain the overriding priority up to the last moment before the shutdown of NPPs that will occur from 2022 on: ensuring high levels of operational safety, verifying the safety culture progress, focus on ageing management and maintenance;

f) Preparation of the regulatory activities dealing with the first transition from operation to safe shutdown of Belgian NPPs - Doel 3 (>2022) and Tihange 2 (>2023): review & assessment of modifications to ensure a safe post-operational phase, inspections of shutdown installations,…

For the **operator (ENGIE Electrabel)**, significant actions to improve safety are planned for the next period 2020-2022:

a) People and processes:

a) Focus on our workforce as nuclear professionals: strategic workforce planning, competence management and leadership in rigor and responsibility;

b) Focus on ageing management in general and ageing management of safety related concrete structures in particular.

b) Remaining design improvements for 2020 in the frame of LTO of Doel 1&2 and Tihange 1:

a) Commissioning of filtered containment venting system in Doel 1 & 2 before restart of the plant in 2020 (in the framework of LTO);

b) Complete the reinforcement of the ultimate systems of the GNS building of Doel 1 & 2 before restart of the plant in 2020 (in the framework of LTO Doel 1 & 2);

c) Commissioning of the SUR-Etendu in Tihange 1 before restart of the plant in 2020 (in the framework of LTO);

d) Complete the reinforcement of the fire protection in Tihange 1 before restart of the plant in 2020 (in the framework of LTO).

II. General Provisions

II.A. Article 4. Implementing Measures

> Each Contracting Party shall take, within the framework of its national law, the legislative, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

After being adopted by the Belgian Parliament, the law endorsing the Convention on Nuclear Safety of Vienna of 20 September 1994 was signed by the King on 26 November 1996 and published in the "Moniteur belge" (i.e. Belgium's Official Journal) of 22 August 1997. As a result, the Convention is incorporated in the Belgian national legislation.

After the ratification, the national legislator decided that the existing legislative and regulatory framework was sufficient to implement the Convention, without adaptations or completions deemed necessary. This does not alter the fact that the efficiency and effectiveness of the regulations are permanently evaluated by the public bodies involved and that they will be improved if necessary, in order to take into account the scientific, technological and social evolutions or to be in compliance with obligations resulting from other international conventions. Since the ratification of the Convention, the nuclear laws and regulations have undergone important modifications, among other things, as a consequence of the operational start-up of the Federal Agency for Nuclear Control (see art. 7 and 8), the adoption of the Law of 31 January 2003 concerning the phasing-out of nuclear energy, the improvement of Health Physics organization through the Law of 7 May 2017 and the promulgation of the Royal Decree on safety requirements for nuclear installations.

II.B. Article 6. Existing Nuclear Installations

> Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of the Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shutdown may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

II.B.1.Nuclear Power Plants (NPPs)

Belgium's seven nuclear power units in operation are equipped with pressurised water reactors built either by Westinghouse or by Framatome, each time in partnership with Belgian manufacturers for the major equipment of the primary and secondary systems. These units were put into service between 1974 and 1985. More details on the seven nuclear power plants can be found in Table 1 and Table 2 of Section I.B and in Appendix 1 of this report.

The process applied for the licensing of these installations was described in previous reports for the Convention. Since the process would no longer be the same today and since many organisations and committees that played a role in this process have been replaced by other organisations and committees, it was deemed no longer appropriate to describe this historic information in this report. However, if needed, the reader can find the information in the 2007 Belgian report for the Convention (in particular in paragraphs II.B, II.D and II.J.1).

After the licensing of the plants, the safety of the installations was continuously reviewed through different processes.

The most important and systematic process is the series of periodic safety reviews (PSR) that have been performed for all seven nuclear power plants. The PSRs are imposed through the operating licence of the facilities and now by the Royal Decree of 30 November 2011 (SRNI-2011).

In addition, many other projects with important modifications have been executed, amongst others steam generator replacements at all units, in some cases accompanied by power increase. Table 5 gives a more complete overview of important projects (besides the PSR):

Summary of the main projects and modifications to the installations		
Year	**Unit**	**Description**
1993	Doel 3	Replacement of the 3 steam generators + power increase
1994	Tihange 2	Introduction of MOX fuel
1994	Doel 3	Introduction of MOX fuel
1994	Tihange 2	Power increase
1995	Tihange 1	Replacement of the 3 steam generators + power increase
1996	Doel 4	Replacement of the 3 steam generators
1998	Tihange 3	Replacement of the 3 steam generators
1999	Tihange 1	Replacement of the pressure vessel head
2001	Tihange 2	Replacement of the 3 steam generators + power increase
2004	Doel 2	Replacement of the 2 steam generators + power increase
2009	Doel 1	Replacement of the 2 steam generators + power increase
2015	Tihange 3	Replacement of the pressure vessel head
2015	Doel 4	Replacement of the pressure vessel head

Table 5 : overview of important projects for the NPPs

Some important projects for the safety assessments of the installations took place in an international context. We refer in particular to the OSART missions undertaken at the Tihange site in 2007 and at the Doel site in 2010. All Belgian plants were also subject to a so-called WENRA Action Plan. This plan resulted from the WENRA RHWG self-assessments and benchmarking project, for which the results were published early 2006. This action plan covered design as well as operational issues and is formally now completed

As mentioned in section II.C.6, a law relating to the phase-out of nuclear energy was voted by the Belgian parliament in January 2003. In July 2012 a governmental decision was taken to allow Tihange 1 to operate until 2025. An action plan has been drawn up for the improvement of Tihange 1, based on the safety assessment report established by ENGIE Electrabel and reviewed by the FANC and Bel V. On 28 June 2015, the phase out law of 2003 was modified to allow the LTO of Doel 1 & 2 up to 2025. As a result, the FANC published conditions, to which ENGIE Electrabel replied with an action plan in 2015. This action plan was based on the initial LTO-project (approved in 2012) and actions from projects (PSR, BEST, …) and operational issues form the period between 2012 and 2015. This action plan was divided into 2 parts: actions (necessary to prove the availability of the safety systems, structures and components (e.g. the qualification or the replacement by qualified equipment of insufficiently qualified equipment; inspections of mechanical or concrete equipment, installation of ageing management programs, …) that had to be executed before the restart and other actions that ENGIE Electrabel had to finish before end 2019 (e.g. the installation of the filtered containment venting system; seismic upgrade of the Refuelling Water Storage Tanks, new seismic fire pump station, …). A selection of important improvement actions in the LTO action plan is given in Appendix 5.E.

The technical characteristics of each unit are described in detail in Appendix 1 to this Report. The original design is described together with the main modifications made since their construction.

A particular characteristic of the Belgian nuclear power plants, that merits to be described in some more detail, is their high level of protection against accidents of external origin. Indeed, for the four most recent units, it was requested at the licensing stage that accidents of external origin had to be taken into account, such as an aircraft (civil and military) crash, a gas explosion, a major fire and the effects of toxic gases. These requirements resulted in a duplication of a significant number of safety systems, installed in bunkered structures to withstand an aircraft crash, which is the most demanding loading case. Moreover, explosive or toxic gases detection systems isolate the ventilation systems in a redundant way in order to prevent the introduction of such gases in the control rooms and of explosive gases in the bunkered part of the installations.

This high protection against accidents of external origin resulted in a greater redundancy or diversity in some cases, of the protection and engineered safety systems. For example, the Doel 3 and 4 units, as well as Tihange 2 and 3, are three loop plants equipped with 3 independent and redundant safety trains (each train having its own safety diesel group in a non-bunkered building) and with 3 emergency trains to mitigate accidents of external origin (each train with a diesel located in a bunkered area and built by a manufacturer different from the one of the normal safety diesels, ensuring diversity). The safety trains and the emergency trains are not designed to cope with the same accidents (of internal origin or of external origin respectively) but the emergency trains provide an equipment diversity which can be very useful even for some accidents of internal origin, according to the probabilistic safety studies results.

Afterwards, the protection against external accidents for the older units (Doel 1 & 2 and Tihange 1) was also considerably improved, amongst others by adding dedicated and bunkered systems to these plants.

Following the Fukushima Daiichi accident, ENGIE Electrabel was asked to conduct Stress Tests. Safety assessment reports for the Doel and Tihange sites have been established by ENGIE Electrabel and reviewed by the FANC and Bel V and external experts. Action plans have been developed. Various modifications were made to the facilities or are in the process of implementation. Specific inspections were carried out at Doel and Tihange to monitor the implementation of these modifications. One of the most important ones is the strong improvement of the protection of the Tihange NPP against external flooding. Improvements form the Stress Test action plan are listed in Appendix 6.

As a conclusion, the permanent in-service monitoring and inspection of the installations, combined with the periodic safety reviews during which the changes in regulations and practices and the systematic use of feedback of operating experience are also taken into account, ensures that the safety of the installations is maintained and even improved where possible. Ageing is systematically investigated in order to ensure the availability of all safety systems.

II.B.2. Research Reactors

Several research reactors were operational in Belgium (5 at the Nuclear Research Centre SCK•CEN and 1 at the University of Gent). At this moment 3 of these reactors (including VENUS, a zero power critical facility), are still in operation; among these, the BR1 and BR2 research reactors that are included in this report. A detailed description of BR1 and BR2 is given in 0.

Following the Fukushima Daiichi accident, SCK•CEN was asked to conduct Stress Tests, which in Belgium were extended to include other nuclear installations than NPP's. Safety evaluation reports, among others for the research reactors in operation, have been established by the licensee and reviewed by the FANC and Bel V. The FANC National report was issued on April 16, 2013. A large part of the actions as defined in the report are finalized.

a) BR1

The BR1 is a natural uranium graphite reactor, comparable to the reactors ORNL X-10 (USA) and BEPO (Harwell, UK). The reactor went critical for the first time in 1956. The core is composed of a pile of graphite blocks thus forming a cube with ribs of 7 meter. The reactor is air cooled. The fuel is metallic natural uranium with an aluminium cladding. Its design thermal power is 4 MW. However, since the start of BR2 this high power was no longer needed and since March 2018 BR1 is licenced to operate at a maximum thermal power of 1 MW using only the auxiliary ventilation system. Due to its very well thermalized neutron spectrum, the reactor is mainly used for neutron studies, such as neutron activation analysis and instrument calibration. Neutronography is also possible.

No significant modifications have been made to the reactor. The original fuel is still loaded. The burn up is still low and hence no replacement is foreseen at this moment. In 1963, after a long period of operation at higher power, the fuel was unloaded and the graphite matrix was heated in order to release the Wigner energy. In the current operating regime, using only the auxiliary ventilation, the graphite temperature is relatively high compared to the fast neutron dose, such that the Wigner energy is still decreasing.

b) BR2

The BR2 is a heterogeneous thermal high flux test reactor, designed in 1957 for SCK•CEN by NDA [Nuclear Development Corporation of America - White Plains (NY - USA)]. It has been built on the site of the SCK•CEN in Mol. Its first criticality dates from 1961 and operation of the reactor started in January 1963.

The reactor is cooled and moderated by pressurised light water in a compact core of highly enriched uranium positioned in and reflected by a beryllium matrix. The maximum thermal flux approaches 10^{15} neutrons / (cm^2.s) and the ultimate cooling capacity, initially foreseen for 50 MW, has been increased in 1971 to 125 MW by replacement of the primary heat exchangers.

The reactor was originally designed for material and fuel testing and this still is an important activity. A number of irradiation devices are available. However, over the past years, isotope production (Mo-99, Ir-192 and others) has become an important activity. Besides that, two irradiation facilities for silicon doping are available.

The beryllium matrix swells under neutron irradiation due to the formation of gas (helium and tritium). This swelling causes cracking of the beryllium which is a brittle material. Furthermore, the build-up of the helium-3 isotope results in neutron poisoning. Due to these effects the lifetime of the beryllium matrix is limited. Three replacements were already performed. The first one took place in 1979 and the second one in 1996. The third replacement was done in 2015-2016 and the reactor was restarted by mid-2016.

During the lifetime of the reactor, continuous modernization projects have been executed. On the occasion of the third beryllium matrix replacement, a major refurbishment programme was realized including the conclusions of the stress test and the conclusions of the Periodic Safety Review of 2016 A new emergency diesel generator system was installed. In the framework of the Stress Tests, a monitoring system is installed that gives information of the state of the installation after a severe accident. The system is designed to work independent of all other systems for at least 72 hrs.

The effort for the conversion from highly enriched uranium to low enriched fuel is being pursued within the HERACLES collaboration, which regroups the concerned EU parties (CEA, ILL, TUM, CERCA). Specific efforts are expended on the industrialization of the LEU fuel fabrication and the development of a back-end solution. The first phase of the HERACLES roadmap is to perform a 'comprehension programme', i.e. understand the previous results and the difficulties encountered with the dispersed UMo fuel system under irradiation; then make the selection of the technical solutions for the qualification of high density LEU fuel and perform an appropriate irradiation programme. These irradiation campaigns were started in 2017 in the BR2 reactor and will continue up to 2023. Post Irradiation Examination for the first plates is started.

SCK•CEN is also looking into an alternative road to conversion. One guiding line is the requirement of the FANC that a proven back-end solution must be in place for the new LEU fuel. Slight and acceptable geometrical modifications to the BR2 standard driver fuel element have been made in order to be able to adopt an evolutionary higher density version of the U3Si2 based LEU fuel system, which in lower density is already qualified for medium power research reactors. These fuel elements are qualified for routine operation and are used from cycle 01/2019. They contain also a different burnable poison, which allows longer irradiation cycles (up to 5 weeks).

II.C. Article 7. Legislative and Regulatory Framework

> 1) Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.
> 2) The legislative and regulatory framework shall provide for:
>   (i) the establishment of applicable national safety requirements and regulations
>   (ii) a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence
>   (iii) a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences
>   (iv) the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation

II.C.1. Introduction

The Belgian legal texts relevant for the safety of nuclear installations covered by this Convention are:

- The Law of 15 April 1994 on the protection of the population and the environment against the hazards of ionizing radiation and on the Federal Agency for Nuclear Control (amended for the last time in 2018),
- The Royal Decree of 20 July 2001 laying down the "General Regulations regarding the protection of the public, the workers and the environment against the hazards of ionising radiation" (GRR-2001, amended for the last time in 2018),
- The Royal Decree of 30 November 2011 on the Safety Requirements for Nuclear Installations (SRNI-2011 amended for the last time in 2018).

Besides these, other legal texts relate to aspects covered by the Convention, such as:

- The legislation with respect to Emergency Planning and Preparedness,
- The law with respect to the Phase Out of Nuclear Energy,
- The legislation on nuclear liability.

The scope of the GRR-2001 is very wide and covers practically all human activities and situations which involve a risk due to the exposure to ionizing radiation, and this at the level of the protection of the workers as well as at the level of the protection of the public and the environment. In particular, the risks associated with the natural radiation (e.g. radon) are integrated in the regulations. These regulations ensure the transposition of all the European directives regarding radiological protection, in particular the 1996 and 1997 directives which considerably strengthened the standards protecting the public, the workers and the environment, and, in particular, the protection of the patients in the frame of medical exposures.

The GRR-2001 implements many articles of the Law of April 15th, 1994 and made **the Federal Agency for Nuclear Control (FANC),** created by that Law, operational. The organisation of the FANC is explained under Article 8. The FANC, which is endowed with wide competences, **constitutes the Safety Authority.**

The texts of the regulations currently in force can be consulted on the website of the FANC (http://www.jurion.fanc.fgov.be).

A summary of the legislation is given below for each main topic. The texts referred to are not frozen, in the sense that they are likely to be replaced, completed or modified at any time by further regulations that amend the original texts, so as to limit the volume of texts to be referred to.

Information concerning the national framework for the management of spent fuel and radioactive waste can be found in the last Belgian National Report for the "Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management", available on the FANC and IAEA web sites.

II.C.2. The Law of 15 April 1994

The Law of 15 April 1994 on "the protection of the population and the environment against the hazards of ionizing radiation and on the Federal Agency for Nuclear Control" constitutes the basic law that sets out the basic elements for protecting the workers, the public and the environment against the adverse effects of ionising radiation. The same law also creates the FANC as the Safety Authority.

- **Chapter 1** defines a number of terms used and clearly establishes (Art. 2) the "Federal Agency for Nuclear Control", abbreviated as "FANC" as the public interest organisation having legal personality to become the Safety Authority.
- **Chapter II** gives more detail regarding the competent authority. The King is the competent authority for all activities involving sources of ionising radiation, including transport. The King may take all measures aimed at protecting the public and the environment in case an unforeseen event presents a danger. The King also nominates the persons in charge of supervising the compliance with this law and its implementing decrees dealing with the medical surveillance of the workers and the health conditions at work (Art. 7-11). These persons trace and record infractions to this law; they can issue warnings and set deadlines for corrective actions; they have access to the nuclear installations at any time; they can proceed to the seizure of equipment or sources;
- **Chapter III** enumerates the various missions of the FANC. Those missions comprise a.o.
  - Control and supervision activities;
  - to perform all acts contributing to this law and to create legal entities contributing to his law;
  - to perform safety and security assessment of nuclear facilities and conduct inspections in those facilities;
  - to examine the licence applications for nuclear facilities; to grant licences for specific facilities, except those with the highest risk (class I facilities); the verification of compliance with licence conditions;
  - radiological surveillance of the territory;
  - to provide technical assistance to the Ministry of Home Affairs in case of nuclear emergencies;
  - to propose and prepare new regulations related to this law;
  - to gather a scientific and technical documentation in the field of nuclear safety; to stimulate and to coordinate R&D;
  - to issue neutral and objective information to the public.
  - The FANC may delegate, on a decision of its Board of Administrators, some of its surveillance missions to legal entities that it has created for this objective
  - The King determines: The missions that can be delegated to the entity; the surveillance of the FANC to the legal entity and the financing mechanism of the entity.
  - The Board the entity is composed of at least 50% of the Board of the FANC
- **Chapter IIIter** has been introduced on December 6th, 2018, to transpose the dispositions of the European Directives 2011/92/UE and 2014/52/UE on environmental assessment of certain projects.
- **Chapter IV** deals with the organization of Health Physics.
  - the licensee has the prime responsibility. Each licensee has to set up an internal health physics department;
  - the King determines the missions, the organization and the working of the health physics department. He also determines the needed resources and competencies;
  - The King determines which tasks have to be performed by a recognized expert. Licensees (of low risk facilities/activities) who have not such expert within their organisation may call upon recognized experts of recognized health physics organization (RHPO);
  - the recognition of those organisations is based on criteria and process defined by the King;
- **Chapter V** deals with the funding of the FANC, which is based on
  - annual taxes on licence holders or future licence holders (e.g. the projects for disposal of radioactive waste); the amounts and the procedure for paying are fixed in this chapter;
  - fees related to the application for a licence, recognition or registration; the amounts are to be fixed by Royal Decree and are adapted annually to the price index;

    - administrative fines; amounts and procedures are detailed in articles 53 to 64 of the law;
    - fees for special (control) activities;
    - gifts and legacies;
    - subsidies.
- **Chapter VI** describes the basic management mechanisms of the FANC
    - FANC is directed by a Board, whose members are appointed by Royal Decree;
    - the Scientific Council, whose composition and duties are fixed by Royal Decree, is established as an advisory body to the FANC;
    - the FANC must be organised is such a way that the regulation development function and the control and supervision functions are carried out independently;
    - day-to-day management of the FANC is entrusted to the General Manager
- **Chapter VII** describes some of the means of enforcement at FANC's disposal such as administrative fines.
- **Chapter VIII** describes some final clauses and some transitional arrangements

II.C.3. The Royal Decree of 20 July 2001

This Royal Decree provides the basic nuclear safety and radiological protection regulations. Amendments are regularly proposed by the FANC in order to take account of scientific and technical developments, to transpose the European directives, etc.

The GRR-2001 introduce the concept of clearance and strict rules concerning the reuse and the recycling of very low level solid waste that also has an important impact on the design, the operation and the dismantling of the nuclear installations concerned by the Convention.

An outline of the GRR-2001 and the provisions that are most relevant in the context of the Convention is given below.

- **Chapter I** – General Provisions
    - Definition of the scope and field of application of the GRR-2001
    - Definition of physical terms.
- **Chapter II** – Categorised Facilities.
    - Facilities are categorised from Class I (the nuclear fuel cycle facilities, representing the highest risk) down to Class IV (very low quantities of radioactive material).
    - Prior licensing is mandatory for facilities from Class I to III.
    - Art. 6 describes the licensing system of the Class I facilities
    - Art. 12 and 13 deal with the licensing issues due to modifications to the facility or the additional licence conditions that can be proposed by the FANC or its scientific council.
    - Dismantling of Class I (and some Class II) facilities is also subject to prior licensing.
    - The competent authority may withdraw or suspend the licence in case of incompliance with the regulations and/or licence conditions
- **Chapter III** – General Protection.
    - The limitation of individual or collective doses is based on the fundamental radiological protection principles: justification of practices, optimisation of protection and individual dose limits. Art. 20 sets out those limits for occupationally exposed people, trainees and students, and for members of the public. It also addresses concerted exceptional exposure, accidental exposure and emergency exposure of the workers.
    - Art. 23 describes the role and duties of the Health Physics Department (HPD) that each licence holder of a facility or operator of a transport company must establish. Under the licensee's primary responsibility, the HPD is in charge of supervising the activities and organizing measures to ensure the protection of the population, the workers and the environment. Specific tasks to be performed by the HPD are listed in Art. 23.1.5. Experts in health physics control

must be recognised by the FANC according to criteria and conditions set out in Art. 73.
    - Art. 24 to 26 deal with the medical surveillance of workers and with the requirements with respect to their training and obligations of the workers to comply with instructions and regulations.
    - Art. 27 to 32 deal with the general protection equipment and arrangements, including individual protection equipment, dosimetry and the use of warning signs.
    - Art. 33 to 37 deal with radioactive waste (solid, liquid and gaseous)
    - Art. 37 bis to 37quinquies deal with the access to nuclear facilities and with the protection of external workers when they are working in a radiation controlled area.
- **Chapter IV** - Dispositions related to legal entities that FANC can create in order to delegate some of its surveillance missions
    - Article 38.1 lists the surveillance missions that the FANC can delegate to Bel V. These missions include on-site surveillance and safety assessments of licensee's projects and activities. By the end of each year, a "control and safety assessment" plan is drawn up, that includes the foreseeable regular controls and safety assessments to be performed next year by Bel V. This plan is approved by the General Manager of the FANC and is send to the licensees in advance. The General Manager of Bel V has to be a recognized expert according to the specifications of article 73. Article 38 also includes provisions to avoid conflicts of interest and to ensure confidentiality of information.
    - The FANC is in charge of the surveillance over Bel V. A Management agreement between FANC and Bel V has to be concluded. Regular reporting is required, and Bel V must maintain a management system in line with international requirements. The FANC can perform audits on the working of Bel V.
    - The average hourly tariff of Bel V is fixed. This hourly tariff is adapted once each year to the consumer prices index in Belgium.
- **Chapters V and VI** deal with medical applications of ionising radiation and are not reported under this convention.
- **Chapter VII** – Transport
    - This chapter has been withdrawn from the GRR-2001 and replaced by the Royal Decree of 22 October 2017 concerning the transport of dangerous goods of class 7.
- **Chapter VIII** – Nuclear Propulsion
    - Construction of any ship or vehicle which is powered by nuclear energy is subject to prior authorisation by the King
    - Ship remaining in Belgian waters or passing through are subject to prior licensing
- **Chapter IX –** Bans and Authorisations deal with specific prohibitions or special licences for using ionising radiation (e.g. sterilisation of medical equipment)
- **Chapter X** – Exceptional Measures
    - Art. 66 deals with the measures against the loss or theft of radioactive substances.
    - Art. 67 deals with the measures relating to accidents, concerted exceptional exposures and accidental exposures.
    - Art. 68 deals with decontamination and,
    - Art. 69 deals with contaminated mortal remains.
- **Chapter XI** - Surveillance of the Territory, the Population and Emergency Planning
    - Article 70 deals with radioactivity monitoring of the territory, and of the doses received by the population, which is taken care of by the FANC.
    - Article 71 deals with the (radiological) monitoring of the population as a whole, the collection of all the data, including those from occupationally exposed workers.
    - Article 72 deals with the emergency response planning for nuclear risks and the information of the population.

    - Article 72bis deals with interventions in cases of lasting exposure.
    - Article 72ter deals with interventions in case of discovery of orphan sources.
    - A specific Royal Decree of 1st March 2018 has laid down the general Emergency planning organisation in case of nuclear/radiological accident (see also section I.C.1.a)(2) and II.C.5).
- **Chapter XII** - **Recognition of Experts**, Physicians and of Health Physics Organisations
    - Article 73 sets all the conditions for the recognition of experts in health physics control.
    - Article 74 deals with the Authorized Health Physics Organizations (RHPOs).
    - Article 75 deals with the recognition of doctors in charge of the medical surveillance of occupationally exposed workers.
- **Chapter XIII** – HASS Sources
    - This chapter has been added in 2006 as part of the transposition of Directive 2003/122/Euratom on the control of high-activity sealed radioactive sources and orphan sources

II.C.4. The Royal Decree of 30 November 2011

The Royal Decree of 30 November 2011 on the Safety Requirements for Nuclear Installations (SRNI-2011) is the result of the WENRA-harmonisation activities with respect to regulation. It also ensures the transposition of the European Directive 2009/71/Euratom on nuclear safety. The SRNI-2011 is composed of several chapters so that it is possible to add specific chapters for specific installations. The following chapters are available:

- **Chapter 1- General Provisions** sets the scope of the Decree and defines terms.
    - The SRNI-2011 applies to nuclear facilities of Class I.
- **Chapter 2 – Generic Safety Requirements** is applicable to all nuclear facilities covered by the decree.
    - <u>Section I – Nuclear Safety Management</u>
    - The licensee shall formulate and communicate to all personnel a safety policy with primary importance to nuclear safety and including a commitment to monitor and to continuously improve nuclear safety (Art. 3)
    - Art. 3/1, added by the Royal Decree of 9 October 2018, introduces the Nuclear Safety Objective from article 8.a of the European Directive 2009/71/EURATOM, as modified by the Directive 2014/87/EURATOM. This Safety Objective is similar to the Vienna Declaration on Nuclear Safety. It also describes the Defence in Depth, in line with the European Directive 2009/71/EURATOM (as amended).
    - Art. 4 states that the organisational structure has to be documented and that nuclear safety management should follow a graded approach to ensure a safe operation of the facility by sufficiently qualified people. The human resources management must take into account the long-term objectives as well as retirement and other cutbacks.
    - An integrated management system (Art. 5) giving priority to safety shall be established, implemented, assessed and improved on a continuous basis. This management system shall cover all the activities and processes which can have an impact on the nuclear safety of the facility, including the activities carried out by the subcontractors or suppliers. Complementary requirements about safety culture have been added by the Royal Decree of 9 October 2018.
    - Art. 6 sets out the requirements with respect to training and formal qualification of the personnel.
    - <u>Section II – Design</u>
    - Art. 7 sets the requirements related to the design basis of the facility. These requirements comprise a.o. the defence in depth concept, the identification of normal operating conditions, anticipated operational occurrences as well as accidents from postulated initiating events (internal and external), fail safe principle,… The design shall also include provisions for future decommissioning purposes.

- Art. 8 requires that a specific process for the classification and qualification of structures, systems and components is in place and that their design, fabrication and maintenance requirements are commensurate with their classification.
  - Section III – Operation
- Art. 9 sets the requirements related to operational limits and conditions. The operational limits and conditions form an integral part of the safety report and shall be reviewed and modified when needed. The limits shall be determined in a conservative manner. In case the operational limits and conditions cannot be complied with, suitable corrective measures shall be implemented and reported to the regulatory body.
- Art. 10 deals with ageing where both the ageing (physical and economic) as well as the ageing management programmes need to be addressed. The ageing management programme shall be reviewed at least during each periodic safety review.
- Art. 11 imposes the licensee to have an operational feedback process in place for collecting, analysing and documenting events that occur in his facility as well as in other similar facilities. This process shall also document the analysis methodologies, notification and distribution of relevant information as well as the process for continuous improvement.
- Art. 12 sets the principles, preparation and implementation of the maintenance-, test-, monitoring- and inspection programmes for structures, systems and components important to safety.
  - Section IV – Verification of Nuclear Safety
- A safety analysis report shall be prepared by the licensee during the licensing phase (Art. 13). The SAR reflects the installations and the activities that are carried out there. This safety report will serve as a basis for addressing the impact on nuclear safety due to modifications and will be updated on a regular basis, according to a specific procedure
- Art. 14 sets the requirements for the periodic safety reviews (PSRs). The main objective of the PSR is to perform a systematic assessment of the nuclear safety of the facility taking into account not only the ageing or modifications made to the facility, but also developments related to regulation and experience feedback. The PSR is to be carried out following a systematic and documented methodology. The PSR shall address 14 safety factors, as listed in the IAEA safety guide SSG-25 and in the WENRA SRLs 2014 publication. A summary report shall be transmitted to the regulatory body that includes the analysis for each safety topic as well as the safety improvement actions and the schedule for implementing these actions. It sets the frequency of the periodic safety reviews at a minimum of 10 years.
- Modifications shall be managed as to guarantee as a minimum the same level of safety as before the modification. Art. 15 details what changes are to be considered as a modification and sets some additional requirements with respect to the safety assessment and the execution of the modification.
  - Section V – Preparation for Emergencies
- Art. 16 sets the requirements related to the internal emergency plan that the licensee has to implement. It specifies the objectives, the preparation and organisational issues. It also states that adequate emergency infrastructure needs to be provided and that the internal emergency plan needs to be exercised at least once per year.
- Art. 17 sets the requirements for the protection against internal fires. The design basis should take into account the main principles of fire protection and this has to be justified via a fire hazard analysis. Fire detection and alarm systems need to be in place as well as passive or active fire extinguishing systems and those systems will be regularly inspected and well maintained.
  - Section VI- Decommissioning [update of August 2015]
- Art. 17/1 is related to the notification of cessation of nuclear activities. It also lists the documents and information that has to be send to the FANC
- Art. 17/2 is related to safety measures and justification of deferred dismantling

- Art. 17/3 sets out requirements about maintaining and adapting the SSCs and the OLCs during the dismantling of the installations
- Art. 17/4 is related to the preliminary qualification of new dismantling techniques
- Art. 17/5 sets out requirements for radioactive waste from dismantling and for (on-site) waste storage
- Art 17/6 sets outs requirements about the management of documents and inventories
- Art 17/7 requires an experience feedback management process (form Belgium and abroad)
- Art. 17/8 sets out requirements about the update of surveillance and maintenance programmes
- Art. 17/9 sets out requirements about the update of the on-site emergency plan
- Art 17/10 gives the tables of content of a dismantling safety report
- Art 17/11 deals with Periodic Safety Reviews during the dismantling phase of the installations
- Art 17/12 deals with the radiological characterisation of the final state and measures to be taken if this state cannot be reached. It also requires the licensee to establish a final dismantling report.

- **Chapter 3** sets the specific Safety Requirements for Nuclear Power Plants
  - Section I – Nuclear Safety Management
  - Art. 18 imposes an organisational entity within the licensee's organisation that is responsible for independent assessments.
  - Art. 19 stipulates specific requirements for operators working in the control room, such as an initial and yearly refresher training on a representative simulator and their authorization.
  - Section II – Design
  - Art. 20 deals with the design basis of existing reactors imposing a defence in depth approach to ensure the basic safety functions: control of reactivity, heat removal and confinement of radioactive materials. It specifies some internal and external events that have to be taken into account. The safety demonstration shall apply sufficient conservatism (e.g. use the most penalising single failure). The design of the safety functions must be such that an operator action is not required for the first 30 minutes. Instrumentation systems shall be used to measure the main parameters. A fall-back control room shall be provided, physically and electrically separated from the main control room. The safety systems shall provide sufficient redundancy and diversity to guarantee that no single failure will cause the loss of the safety system and that the shutdown of one component or one line will not cause the loss of minimum required redundancy. Emergency power supplies have to be available, capable of providing the necessary power.
  - Art. 21 deals with the design extension, i.e. beyond design basis accidents and severe accidents (involving core damage). Specific instrumentation shall be provided for managing those accidents in both the main control room and the fall back control room. For specified design extension (DEC-B) accidents, the containment must be maintained as much as possible.
  - Art. 22 states that interfaces shall be present to prevent that a failure of a structure, system or component of one class induces a failure on a system of a higher class.
  - Section III – Operation
  - Art. 23 imposes operational limits and conditions to cover all operational states of the nuclear power plants and that the personnel of the control room and the supervising personnel has sufficient knowledge of the limits and their technical basis.
  - The licensee shall develop an ageing management programme (Art. 24) that takes into account a.o. the operational conditions and load cycles. The main systems, structures and components shall be monitored to detect effects due to ageing in a timely manner to allow for preventive or corrective measures.

  - Art. 26 defines the minimal requirements for the leak tests of the reactor primary circuit and to verify the integrity of the containment.
  - The licensee shall complete a set of accident management procedures including severe accidents (art. 27). Accident management procedures are to be used during accident conditions when there is no damage to the core and their main objective is to restore safe conditions, restore or compensate the loss of safety functions and to prevent or delay core damage. In severe accident conditions, or when there is damage to the core, the severe accident management procedures are to be used, with the aim to limit further core damage, preserve as much as possible the integrity of the vessel, limit the release of radioactive substances and to restore controlled conditions. The accident management procedures shall be developed on the basis of realistic scenarios, using deterministic and probabilistic analysis techniques. They shall be available, easy to identify and to use, and the transition from accident management procedures to severe accident management guidelines is clearly identified. They shall be inspected and validated, as well as updated periodically. Personnel that could be concerned by those procedures shall receive adequate initial training and refresher training.
  - Section IV – Verification of Nuclear Safety
  - Art. 28 defines the minimal content (16 chapters) of the safety analysis report.
  - A level 1 and level 2 probabilistic safety assessment (PSA) shall be performed for each reactor and for each operating mode (Art. 29). For level 2 the PSA could use however a representative unit. The PSA shall use realistic assumptions and shall take into account aspects such as internal fire hazard, external events, human interventions and human errors. Level 1 PSA shall include a sensitivity and uncertainty analysis, level 2 PSA at least a sensitivity analysis. The PSA results shall be used during the design and operation of the power plant e.g. as a decision making aid or to check the adequacy of modifications.
  - Art. 30 has been withdrawn and transferred to article 14.
  - Section V – Preparation for Emergencies
  - A coordination centre for managing on-site events shall provide communication equipment to the control room, the fall-back control room and with all major locations on the site, as well as with on-site and off-site emergency organisations (Art. 31).
  - Art. 32 specifies specific requirements for protection against internal fires. These requirements include e.g. a fire PSA and the maintenance of the safety function during and after a fire occurrence.
- **Chapter 4** has been included in May 2018 and contains the WENRA reference levels related to the safety of radioactive waste and spent fuel storage and treatment.
- **Chapter 5** contains some final provisions and transitional arrangements

II.C.5. The Royal Decree of 1 March 2018 on Emergency Planning

The law of 15 May 2007 defines the notion of Civil Protection and describes the roles and missions of the different entities involved. The Royal Decree of 22 May 2019 organises the emergency and intervention plans. The Royal Decree of 1 March 2018 lays down the nuclear and radiological emergency response plan and the tasks of each of the parties involved.

According to article 16 of the SRNI-2011, it is mandatory for nuclear installation operators to set up an internal emergency plan and to get it approved by the Regulatory Body. This plan shall be tested regularly to address possible accidents. The intervention of the Authorities outside the affected installations takes place under the authority of the Minister of Home Affairs, who supervises the Civil Protection.

The nuclear and radiological emergency plan for the Belgian territory aims at co-ordinating the protective actions for the population, the (emergency) workers and the environment in the event of a nuclear accident or any other radiological emergency situation that could lead to an exposure of the population above the routine limit (1 mSv/y) or to a significant contamination of the environment.

This document will serve as a guide for the protective actions to be implemented, should a radiological emergency occur. It establishes the tasks that the various departments and organisations would have to accomplish if the case arises, each within their legal and regulatory competences.

The provisions of the emergency plan apply in the cases where there is a risk of significant radiological exposures to the population in any of the following ways:

- external irradiation due to air contamination and/or deposited radioactive substances;
- internal irradiation by inhalation of contaminated air and/or ingestion of contaminated water or food.

The Nuclear and Radiological Emergency Plan for the Belgian territory (NEP) is mainly designed for emergency situations in the major Belgian nuclear installations: the nuclear power plants of Tihange and Doel, the Nuclear Research Centre in Mol, the Institute for Radioelements in Fleurus, the waste treatment and storage installations of Belgoprocess in Dessel and the European Joint Research centre in Geel. This plan is also activated for other emergency situations, which can occur during transport on the Belgian territory (accident during the transport of nuclear material from the nuclear fuel cycle or waste from fuel reprocessing) or radiological emergency resulting from a terrorist attack or a malevolent act.

The NEP also addresses events occurring in neighbouring nuclear installations located within a distance of 100 km from the border (i.e. Chooz, Gravelines and Cattenom NPPs in France and Borssele NPP in The Netherlands).

In case of an emergency, the off-site operations are directed by the National Crisis Centre, under the authority of the Minister of Home Affairs. The implementation of the actions decided at the federal level and the management of the intervention teams are under the leadership of the Governor of the Province concerned.

The plan describes the overall organisation. It has to be completed by concrete internal plans based on the intervention, at various intervention levels, of:

- the provincial authorities;
- the municipal authorities;
- all the intervening institutions.

Belgium is contracting party to both the Convention on Early Notification of a nuclear accident and the Convention on Assistance in the case of a nuclear accident or radiological emergency.

II.C.6. The Law of 31 January 2003 on the Phase-out of Nuclear Energy

According to article 4 of the law of 31 January 2003 on nuclear phase out, the operation of the Belgian NPPs was initially limited to 40 years. This law has been amended two times, on July 4th, 2012 and on June 28th, 2015 respectively to allow a continued operation for 10 more years for Doel 1, Doel 2 and Tihange 1.

The construction of new NPPs is forbidden (Article 3) in Belgium.

II.C.7. The Licensing regime for nuclear installations

Since 2001, the new licensing process for facilities of class I comprises two phases, each one ending with a Royal Decree.

The licence application consists of three parts:

- The first part consists mainly of administrative information, defining amongst others responsibilities, names and legal status of the applicant, …
- The second part consists of a preliminary safety analysis report containing amongst others:
    - the safety principles that will be applied for the construction, the operation and the design basis accidents,
    - the already available probabilistic safety analysis,
    - the qualification of the mechanical and electrical equipment,
    - the principles that will be applied for quality assurance,
    - the expected quantities of waste and their management, including those related to the dismantling,

- The third part of the application consists of an environmental impact assessment report, including as a minimum the general data referred to in the recommendations of the European Commission on the application of Art. 37 of the Euratom Treaty (99/829/Euratom); this report must also comply with the European directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (as amended by European directive 2014/52/EU).

Belgium is a federal state composed of three Regions being legally competent for environmental protection on their territory (radiological aspects excluded) and thus also for the granting of related environmental licences. To coordinate the process and ensure the coherency of the application files, cooperation exists between the FANC and the competent authorities of the Regions.

The licence application is examined by the FANC. The advice of the Belgian Waste Management Agency (ONDRAF/NIRAS) is requested for the waste and future dismantling of the facility aspects. The file is then presented for advice to the Scientific Council of the FANC. A mandatory international consultation (application of Article 37 of the Euratom Treaty on the trans-boundary impact) and/or a voluntary consultation of the European Commission may take place. Following the advice of the Scientific Council, the file is submitted to a public enquiry and to the involved municipal authorities for advice, and then to the executive of the involved provinces. The completed file is sent back to the Scientific Council for final advice. A positive advice of the Scientific Council is necessary for a positive decision. The Scientific council can also propose particular conditions to be attached to the licence, related to the commissioning of the installations or in view of ensuring the safety and the wholesomeness of the future installation. This construction and operating licence allow the applicant to build the installations in conformity with the licence.

The second phase addresses the confirmation of the construction and operation licence. The licensee's Health physics department is primarily in charge of the acceptance of the installations. Bel V acting on behalf of the FANC verifies the acceptance of the installations before the start up. After a fully favourable acceptance, the FANC can propose to the King a confirmation decree allowing operation of the facility.

Partial confirmation decrees are possible, each based on a fully favourable acceptance report. The confirmation decree can also modify or complete the conditions attached to the initial licence.

Note that this licensing system is currently being reviewed, in order to explicitly align it with the European Directive 2014/52/UE *on the assessment of the effects of certain public and private projects on the environment* and to improve consistency between the licence application and the requirements of the SRNI-2011.

The licensing process is illustrated in the figure below.

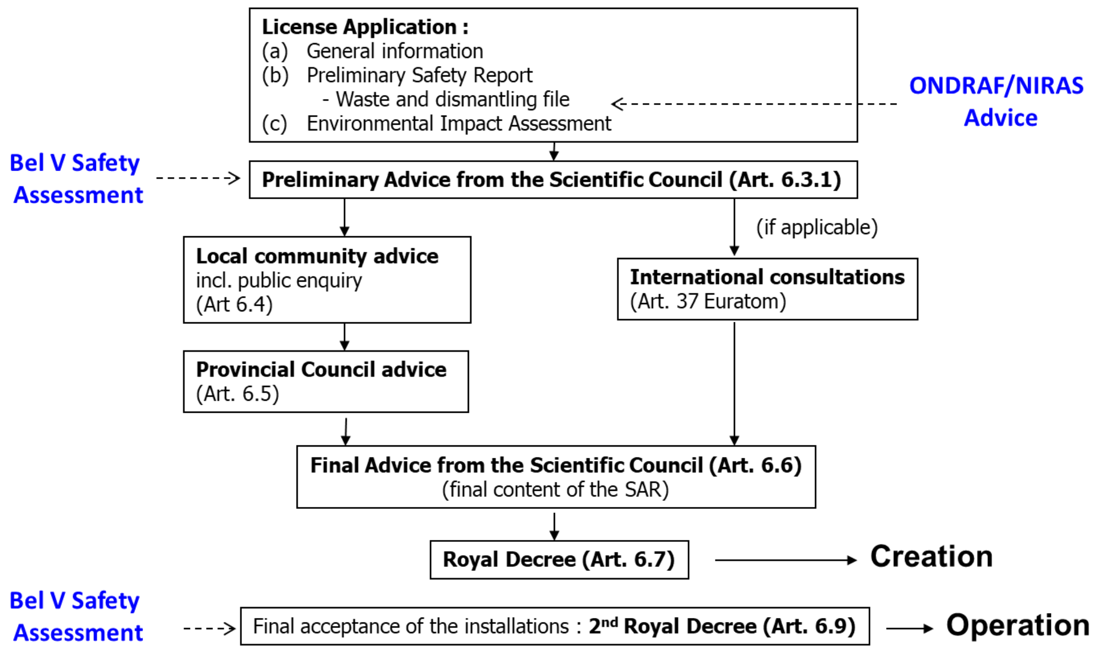

Figure 5 : Licensing process for Class I Facilities

Appeal against the FANC decisions and authorisation decrees.

The construction and operation licence of Class I facilities is granted by Royal Decree on the proposal of the Minister of Home Affairs. Like any decree, anybody can introduce an action for annulment of the decree, during 60 days after the publication of the decree.

The body in charge of treating the appeal against the decree is the "Council of State". If the situation is urgent or if it is needed, on request of the applicant, the council of state can suspend the decree immediately.

Modification of the licence:

The licence and the conditions attached to the licence can be modified in two ways:

- At the initiative of the operator. According to article 12 of GRR-2001, any project to modify the facility must be notified to the FANC. If the proposed modification has a significant impact, the FANC can decide whether the licence or the conditions attached to it, have to be amended.
- At any moment, at the initiative of the FANC or at the initiative of its Scientific Council, according to article 13 of GRR-2001.

In these cases, the process for modification of the licence is similar to the initial licencing process. Derogations from administrative formalities are possible, but advice of the Scientific Council is always mandatory.

II.C.8. Conclusions regarding the provisions of Article 7

By becoming fully operational in September 2001, the FANC has taken over the tasks aiming at the enforcement of the Law of 15 April 1994 and its implementing decrees, in view of the radiological protection of the public, the workers and the environment.

In Belgium, there is a legal and regulatory framework for safety of nuclear installations for almost 50 years.

The laws and Royal Decrees are regularly updated, and completed or, if necessary, amended (for instance to take into account the Euratom Directives, the international treaties signed by Belgium, etc.).

The legislative and regulatory framework comprises:

(i) a set of laws and regulations (cf. description above), including safety requirements based on the WENRA reference levels (which are based on the IAEA safety standards),

(ii) a licensing regime for nuclear facilities and activities, and the prohibition to operate an installation without a licence (cf. GRR-2001 and, among other, its articles 5, 6, 15, 16, 79 as well as all the Articles detailing the technical stipulations),

(iii) a regulatory inspection and assessment system of the nuclear facilities and activities, to verify compliance with the regulatory provisions and conditions attached to the licence (cf. GRR-2001, among other its Articles 6, 12, 13, 15, 16, 23, 78), the organisation of which is detailed in section 0.

(iv) Measures intended to enforce compliance with the relevant regulatory provisions and the conditions attached to the licence, including the suspension, amendment or withdrawal of licences (cf. GRR-2001, among other its Articles 5, 12, 13, 16) as elaborated in section II.D.2.

II.D. Article 8. Regulatory Body

1) Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.
2) Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organisation concerned with the promotion or utilisation of nuclear energy.

Since 1 September 2001 the supervision of nuclear activities is the responsibility of the Federal Agency for Nuclear Control (FANC), which constitutes the Safety Authority. This mission has been entrusted to the FANC by the Law of 15 April 1994. According to articles 14ter of this law (as amended by the law of 7 May 2017), the FANC can create legal entities to assist it in the execution of its missions. The FANC has made use of this provision and created Bel V in September 2007, a subsidiary with the statute of a so-called 'foundation' as defined in Belgian law. The FANC delegates several regulatory tasks to Bel V, a.o. on site routine inspections – albeit without associated enforcement powers – and independent safety assessments. Only Class I facilities (including NPPs and Research Reactors) and some higher risk Class II installations – the so called Class IIA – are inspected by Bel V.

It is through the association of the FANC on one side, and Bel V on the other that the function of regulatory body as stipulated in article 8, is ensured.

A control structure with 3 levels is in place: first by the licensee's Health Physics Department (HPD), then by Bel V which performs by delegation of the FANC a number of inspections and safety assessments, and finally by the FANC, who is the Safety Authority. This structure is illustrated below:

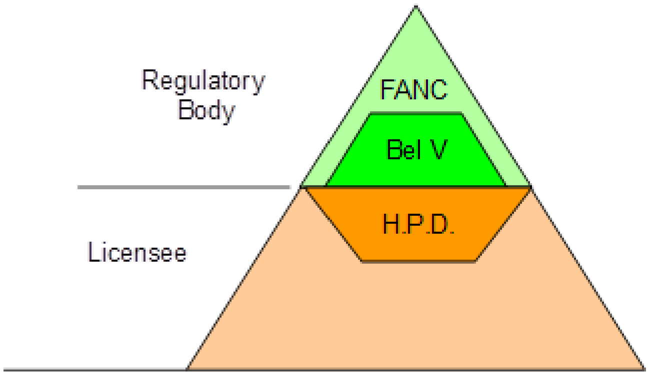

Figure 6 : 3-level control structure

The descriptions in this article focus on the tasks relating to the installations covered by the National Report, and consequently are not an exhaustive overview of all the regulatory functions assumed by various organisations.

II.D.1. Mandate and Function of the Regulatory Body

Mandate and functions of the regulatory body are defined in the Law of 15 April 1994.

The Belgian regulatory body fulfils regulatory functions as described in the IAEA Safety Guide GSR part1:

The regulatory function "*development of regulations and guides*" is allocated exclusively to the FANC. The FANC has the duty to make regulation proposal to the King (i.e. the Government). Since 2017, the FANC can also issue binding technical regulations, of a non-policy nature, in cases foreseen in a Royal Decree. Both FANC and Bel V can also issue technical guidances but these guidances are not binding.

The regulatory function "*licensing*" is ensured by the FANC. For the nuclear installations covered by this Convention, the King (the Government) is the competent authority to issue licences. The FANC investigates the licence applications and proposes the licences and conditions attached to it.

The regulatory function "*assessment*" is allocated to the FANC, which delegates, for the installations covered by this Convention, parts of this function to Bel V.

The regulatory function "*Inspection*" is allocated to the FANC, which delegates, for the installations covered by this Convention, parts of this function to Bel V.

The regulatory function "*Enforcement*" is allocated exclusively to the FANC (see next section II.D.2).

Other additional functions are allocated to the FANC, with possible support from Bel V:

- radiological surveillance of the Belgian territory,
- participation to the national nuclear emergency planning and response,
- communication with the public and political authorities

Security matters are also within the mission of the FANC and are entrusted to its department "transport and security".

a) Delegation of regulatory functions to Bel V

The list of regulatory tasks that can be delegated by the FANC to Bel V is fixed in article 38.1 of the GRR-2001. These tasks consist of:

- Regular on-site inspections on "Class I" facilities, for the permanent supervision of the good performance (including approbation of some decisions) of the licensee's Health Physics Department. This permanent supervision in practice consists of systematic, thematic and specific inspections devoted to defined subjects (operation, periodic tests, chemical control, radiological protection …) and specific items follow-up inspections, examination of modifications and incident analysis. An inspection report is written following each field inspection, which is also sent to the FANC.
- Safety assessments of licence applications and of acceptance of new installations and of modifications
- Safety assessments and on-site inspections of other licensee's projects (e.g. PSR, Licensee's action plans)
- Safety assessments of the files and safety analyses related to the SRNI-2011 that are submitted by the licensee.

The Board of Administrators of the FANC formally delegated those tasks to Bel V on March 1st, 2019.

A 6-year integrated inspection strategy is developed jointly by the FANC and Bel V. An annual programme for inspections is derived from this strategy and is communicated yearly to the licensees. A revision of this strategy is possible each year, in order to take into account experience feedback from the previous years.

The annual inspection and safety assessment programme of Bel V is approved by the FANC.

Bel V informs the FANC on its findings on a regular basis. In particular, any situation that may have an impact on the public, the workers or the environment is immediately communicated to the FANC.

Each year, Bel V makes an evaluation of the safety of the installations it inspects and draws up the lessons learnt.

The FANC has several means to monitor the good performance of Bel V, see section II.C.2 (Chapter III of the Law of 15 April 1994) and II.C.3 (Article 38 of GRR-2001):

b) Collaboration FANC-Bel V

A collaboration agreement between FANC and Bel V is established, and covers a.o. the following areas:

(1) Support to the FANC activities

Bel V supports the FANC for technical aspects related to public communication, including INES evaluations.

(2) Advice on regulation proposals

Bel V collaborates with the FANC to give advice on new regulation proposals, on the application of regulations, and on regulation gaps and shortcomings.

(3) Cooperation in international activities.

Bel V and FANC activities are coordinated in a structured manner in the field of international multilateral and bilateral activities and representations, in particular in the frame of WENRA, the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

(4) Research and Development

A coordination is established between the FANC and Bel V for the research and development activities, in order to ensure complementarity, search synergies and ensure circulation of results.

(5) Knowledge management, improvement and development of knowledge.

A collaboration is established in the field of knowledge management.

(6) Emergency Preparedness and Response

In case of an emergency, Bel V collaborates with the FANC for technical and radiological evaluations of the emergency in the evaluation cell (CELEVAL).

Additionally, an internal crisis centre is set up and maintained by the FANC. The FANC and Bel V are jointly responsible for the setting up of the procedures, for the staffing and for allocation of resources during emergency situations.

Finally, Bel V assists the FANC in the review of security plans or in the field of cybersecurity on request by the FANC.

II.D.2. Enforcement of applicable regulations and of the terms of the licences

The enforcement power of regulatory requirements is given to the FANC by the legislation. The enforcement tools and measures are provided in the following legal documents:

- the Law of 15 April 1994;
- the GRR-2001;
- the Royal Decrees of December 20, 2007 related to administrative fines

Various coercive measures are used to reinforce FANC's orders. Two types of sanctions are foreseen in the Law of 15 April 1994 (articles 50 to 64): legal penalties (requiring a legal procedure by the Court) or administrative fines (nevertheless requiring an information to and a decision by the Public Prosecutor).

The FANC nuclear inspectors are nominated by Royal Decree. They have enforcement powers; they can also intervene on the request of Bel V inspectors. The FANC inspectors can also take any measure they consider necessary to reduce or eliminate hazards for workers, the public and the environment. These measures can include warnings, requests for corrective actions with a delay not exceeding 6 months (article 9 of the Law of 15 April 1994).

The choice of the enforcement measures is based primarily on the safety significance of the infraction or situation where corrective measure are required, applying the principle of graded approach. The enforcement policy is presented in the FANC management system.

The nuclear inspectors have to take any necessary and urgent measures to avoid or eliminate a risk. Examples of those measures are:

- Impose technical modifications to the installation (additional shielding, installation of additional detection device);
- Proceed to the seizure or evacuation of radioactive sources, contaminated material or devices that present ionising radiation;
- Impose an administrative modification (as far as procedures, instructions or operating modes are concerned) or an organisational modification (obligation of additional personnel in relation to security and/or radiological protection);

In extreme cases and if a practice may result in a specific danger (e.g. detriment of health), the nuclear inspector has the power to interrupt the activity.

Bel V is delegated by the FANC to permanently supervise whether the operator complies with the regulations in force and with the conditions attached to the licence, but only has the power to make recommendations. Should the operator violate the conditions set in the licence and fail to correct that situation, or should the operation evolve towards an unsafe situation, this would be referred to the FANC who will proceed to enforcement measures.

Another possibility to strengthen safety is foreseen in article 13 of the GRR-2001: The Safety Authority (The Scientific Council or the FANC services in charge of the supervision) can, on its own initiative and at any moment, propose additional conditions to be attached to the licence with the aim of improving safety.

Finally, if the licensee does not comply with the regulations or with its licence, a process described in article 16 of GRR-2001 allows the FANC to propose to the King the suspension or the withdrawal of the licence, after advice of the Scientific Council for Class I facilities.

II.D.3. Structure of the Regulatory Body, Financial and Human Resources

a) The FANC

The law of 15 April 1994 defines the statute, the missions of the FANC, as well as some requirements about its internal administration.

The Federal Agency for Nuclear Control (the FANC) is an autonomous public institution with legal personality.

The FANC is institutionally and financially independent. The FANC is led by a non-executive 14-headed Board of Administrators. The members of the Board of Administrators are appointed by Royal Decree, on the proposal of the Council of Ministers. In order to guarantee the independence of these board members, their mandate is incompatible with certain other responsibilities within the nuclear sector and within the public sector. The governance charter of the Board of Administrators is published on the FANC website. The board, which meets about six times a year, is in charge of:

- the overall long-term and short-term strategy, with the approval of the medium-term and annual operational plan;
- the conditions of recruitment and employment of the FANC staff;
- the financing of the FANC.

The Board approves the FANC annual budget and staffing levels.

The FANC is supervised by the Federal Minister of Home Affairs via a government Commissioner who attends the meetings of the Board of Administrators. The Board delegates the management of the FANC to the General Manager (Director-General) who is appointed by Royal Decree for a term of 6 years.

The FANC, as a public body, reports to Parliament through the Minister of Home Affairs, thus ensuring legal independence with other government agencies and ministries that promote the use of ionizing radiation for a variety of purposes.

In order to perform its tasks, the FANC is assisted by a Scientific Council [established by article 37 of the law of 15 April 1994]; the composition and the competences of this Council are fixed by Royal Decree. The Council consists of high-level experts within the field of nuclear energy, nuclear safety and radiological protection.

The FANC exercises its authority with regard to the nuclear operators through one-sided administrative legal acts (the consent of the involved operators is not required) such as the granting, refusal, modification, suspension and withdrawal of licences, authorisations, recognitions or approvals. It organises inspections to verify the compliance with the conditions attached to the licences, recognitions and approvals. The FANC can claim any document in whatever form, from the facilities and companies under its supervision.

The operation of the FANC is entirely and directly financed by the companies, organisations or persons to whom it renders services. In practice this is done through non-recurrent fees and annual taxes at the expense of the applicants or holders of licences or recognitions. The amount of the taxes is set in article 30bis of the law of 15 April 1994, the amount of the fees is fixed by Royal Decree, as foreseen in article 30quater of the law of 15 April 1994. The receipts and expenditures of the FANC have to be in equilibrium.

The above-mentioned statute confers to the FANC the indispensable independence to enable it to impartially exercise its responsibilities as a regulator of the nuclear activities - as prescribed in art. 8 of the Convention on Nuclear Safety.

More information is available on the website: www.fanc.fgov.be

Below the General Manager, the FANC is organized in four departments: the Department "Facilities and Waste", the Department "Security and transport", the Department "Health and environment" and the Department "Support".

The FANC organisation chart can be drawn as follows:

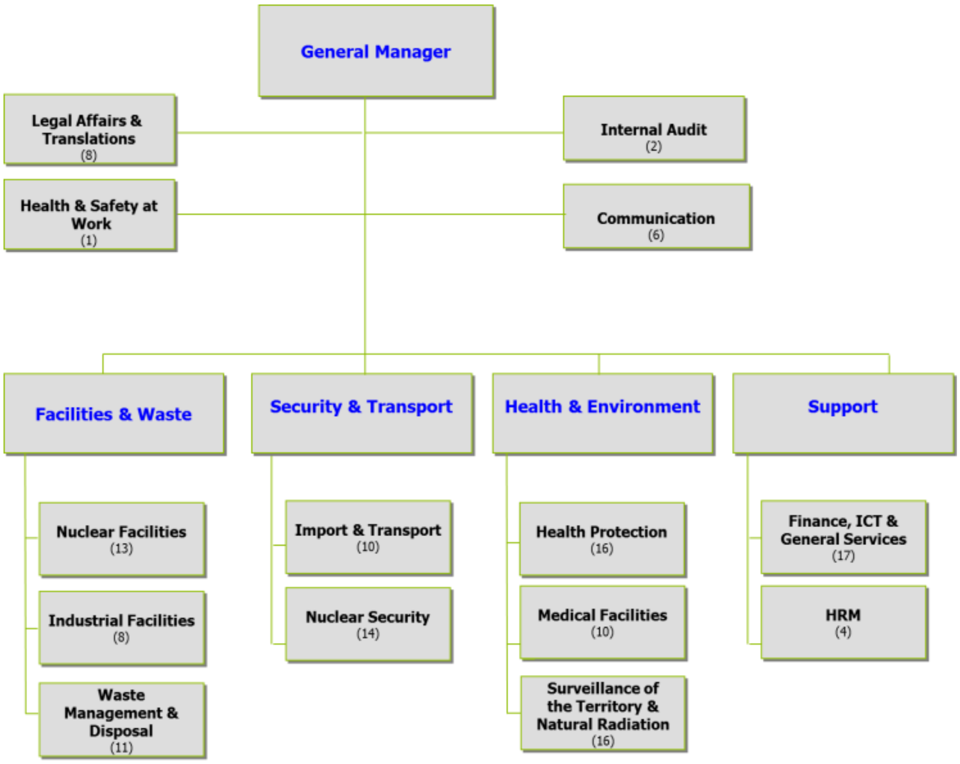

Figure 7 : Organisational chart of FANC

The missions of the department `Facilities & Waste' relate to nuclear and industrial facilities, management of radioactive waste, and recognition of qualified experts in Health Physics.

- The first mission includes the inventory, the analysis and the evaluation of licence applications. This mission consists of ensuring that ionizing radiation can be used safely and that a licence can be granted.
- The second mission involves the control, the inspections and the investigations that ensure that the activities carried out comply with the licence and its conditions, and, in a more general way, with the regulations in force. In addition, the department must also track down any illegal activity carried out without authorization. Synergy between these two missions mainly aims at improving: 1) the safety in general, and 2) the protection of the workers, the public and the environment against the hazards of ionizing radiation.
- The third mission includes the contribution to a regulatory framework for the disposal of radioactive waste of different categories, as well as the licensing of disposal facilities.
- Finally, the department makes regulation proposals in its field of activities and develops the related technical regulation and guidance

The department `Security & Transport' is responsible for the physical protection of nuclear material, and for the regulation of transport, import, transit and export of radioactive material. Here also, the licensing activity as well as the surveillance of a specific activity have been integrated in the same pillar, with the objective of optimizing the exchange of information and setting up a more effective control policy.

The department `Health & Environment' is in charge of the activities relating to man and his environment (including the radiological monitoring network TELERAD). This operational entity is directed towards the protection of the public, the workers and the environment in all fields, namely the medical and veterinary applications, the natural radiation sources, the radiological surveillance of the territory, the national nuclear emergency plan and the clean-up/restoration of contaminated sites.

The department `Support' is in charge of the activities at the organizational level and activities involving several departments (horizontal activities):

- human resources management at the FANC level;
- follow-up of FANC projects;
- follow-up of international activities;
- finances and Information Technology.

At present, the personnel of the FANC is composed of about 150 persons. This figure is stable for around 10 years. More than 60 % of them are university graduates in different fields of science (physics, chemistry, biology, medicine), engineering, law, economics, social sciences and communication.

b) The Management system of the FANC

Since 2008 the FANC has had a quality management system that conformed to ISO 9001:2008

The FANC core processes and related support processes have been identified by the FANC management team and were integrated into the existing quality system in 2008. A complete review of the management system started after the self-assessment in 2012 and the IRRS mission in 2013, with the aim to comply with IAEA Safety Requirements, GS-R-3 (now GSR part 2).

This resulted in a new mapping of the management system and integrating policies, intention plans (strategy, operational objectives), and operational and support processes.

The FANC management system consists of:

- a governance document "Management *system policy*" which describes how missions and responsibilities entrusted to the FANC by the Law of 15 April 1994 are discharged through the different FANC departments;
- the "*Strategic plan*" which is established on a timeframe of 9 years. This strategic plan is translated in a 3 years operational plan and finally in an annual operational plan including the assigned resources;
- *FANC policies*, developed in accordance with the FANC missions and the Strategic plan and validated by the senior management. They have committed themselves to follow the quality policy requirements and request every FANC employee to do the same.
- *procedures*, described in the FANC management system are derived from the legislation and the FANC policies.

The processes include licensing, inspections, incident and accident management, environmental surveillance, security, enforcement, development of regulations and guides, international relations, projects and development, human and financial resource management, communication, ICT management, legal affairs, and record and information management.

The concept of continuous improvement is being applied to the FANC organization, to the management system, and to the individual workers at FANC.

An annual Management Review is conducted on the quality aspects, including results of internal/external quality audits, corrective/preventive actions, non-conformities, complaints, and customer satisfaction surveys and financial aspects.

c) Foundation Bel V: Overall organisation

Bel V is a non-profit 'foundation', created by the FANC.

Bel V must perform on-site inspections with inspectors that have to be recognised experts according to article 73 of the GRR-2001, ensuring the inspector meets the education and training requirements and has at least three years of experience in the nuclear field. Bel V's personnel training budget amounts to about 10 % of its overall budget in man-hours.

At the end of 2006, in view of ISO-certification, a process oriented organisation has been implemented. Among these processes, the most important ones from a safety point of view are: to manage projects/missions (manage safety assessment projects and inspection projects), to perform inspections, to provide and to manage expert services (perform safety assessment activities), to manage expertise and technical quality, to manage and to develop human resources. These processes are managed by process managers who are accountable for the realisation of goals and the quality of the activities performed in the process they are in charge of.

Bel V's technical personnel is composed of 74 (70 full-time equivalent on 01/04/2019) university graduates (engineers and scientists), and recruitment is in line with the foreseeable workload. The workload consists of a more or less constant portion related to inspection of installations, and a more variable load in time related to the progress of the licensee's projects and the number of safety assessments to be performed, and also to the assessment of incidents or specific safety problems in the installations in Belgium or abroad.

d) Bel V: Technical Activities

Besides the hierarchical structure in 3 departments, Bel V's technical staff, regardless of which department they hierarchically belong to, is attached to "Technical Responsibility Centres" (TRC), "horizontal" cells in charge of exercising nuclear safety and radiation protection expertise and of maintaining the knowledge in the various technical specialities.

As of the end of the year 2006, Bel V's technical staff has carried out the technical activities within the operational processes as described above.

The management of all TRCs is performed within the process "Provide and manage expert services", managed by a process manager, in order to give it better support and have a harmonized approach.

The process "**Perform inspections during operation**" is in charge of inspections in all nuclear installations supervised by Bel V.

For the nuclear power plants, one Bel V engineer is assigned to one nuclear unit (hence 3 engineers for Doel, as the Doel 1 & 2 twin units are considered as a single unit, and 3 engineers for Tihange) and the managerial staff examines the problems common to a site as a whole, oversees the coherence of approaches between the sites and ensures experience feedback between all the Belgian units.

The activities performed in this process also include inspections in installations other than nuclear power plants, such as other class I facilities as well as class IIA facilities (universities, hospitals,…).

The process also includes the Bel V activities related to its participation in the national emergency plan at the level of the evaluation cell (see article 16, section II.L.2). It also participates in the emergency plan exercises related to the Belgian nuclear installations (nuclear power plants and other facilities), as well as in the exercises of foreign nuclear power plants located near the Belgian border, through bilateral or international collaborations. The follow-up of all national and international projects linked to the operation of the installations is performed in the framework of the process "**Technical Management of the projects/missions**".

At the national level, examples have been the increase of the length of the cycles and the higher burn-ups, the power increase and the replacement of steam generators, the periodic safety reviews, the European "Stress Tests", the long term operation of NPPs, the pre-licensing process of the MYRRHA Accelerator Driven System, the pre-licensing process of new on-site interim spent fuel storage facilities for the Doel and Tihange sites, safety assessment of a waste disposal facility.

At the international level, the co-operation with the Safety Authorities of several countries outside the European Union (bilateral aid or INSC contracts of the European Commission) is continued.

In the frame of the periodic safety reviews, Bel V follows the evolution of the safety standards in the world (USA, Member States of the European Union, IAEA…) and examines with the licensees which new standards should be followed.

Safety assessment is performed in the framework of the process "**Provide and manage expert services**". It covers support to inspection activities, the analysis of significant modifications, and analysis having a more general character: generic studies valid for all nuclear power plants, probabilistic safety assessment developed specifically for each unit but where the analysis methodologies must be identical, applications of these probabilistic studies in particular to the analysis of operational events, severe accident management, safety requirements for future reactors, safety analysis for the disposal of radioactive waste.

Research and Development activities in which Bel V participates (international projects like research and development activities within programmes financed by the European Commission, bilateral and own developments in Bel V) are managed in the framework of the process "**Management of expertise and technical quality**".

Alongside its own experts, Bel V calls only very exceptionally on services from outside specialists (universities, research centres): on the one hand these should not have worked in the past on behalf of the operator on the subject, and, on the other hand, full definition of the scope, framework and precise objectives of the task or studies that would be subcontracted represents a non-negligible part of the overall effort and time that can be devoted to the job. Examples of Bel V's calling on outside expertise concerns the evaluation of neutron-ageing of the aluminium reactor vessel of the BR2 reactor or the reactor pressure vessel flaw issue of Doel 3 and Tihange 2 reactors and, support in developing

MELCOR input decks, or the recent concrete problems in the bunkered steam exhaust rooms of several nuclear power plants (see section I.C.4.b).

The organisation chart of Bel V is given below (the figures in brackets give the current staffing):

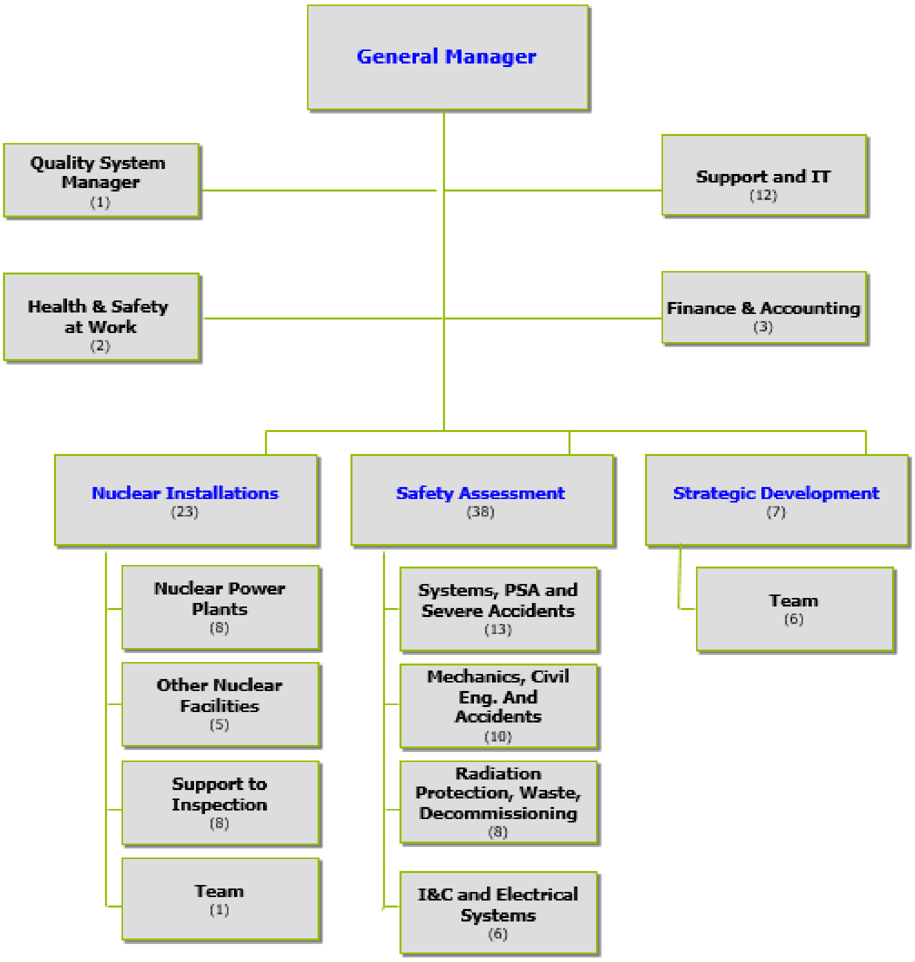

Figure 8 : Organisational Chart of Bel V

e) *Funding of Bel V*

Bel V is a non-profit organisation. It is funded by the licensee, for the on-site controls and safety assessments it performs as foreseen in the approved annual inspection and safety assessment programme, on the basis of a pre-defined average hourly tariff. This tariff has been fixed in article 38 of the GRR-2001, as modified by the Royal Decree of 6 December 2018.

Due to Bel V being a non-profit organisation, its financial resources are used for the payment of its personnel and related costs, for the participation in national or international working groups, for personnel training, for its research and development activities and for the maintenance of technical and regulatory documentation.

II.D.4. Position of the Regulatory Body in the Governmental Structure

The Safety Authority (FANC) is a public interest body with a large independence that reports to its supervising minister, the Minister of Home Affairs.

The FANC has the duty to communicate with the public. Therefore, they answer for instance any questions and requests for information received from the Government, Members of Parliament or from others.

The FANC annually presents its report of activities to the Parliament.

Bel V is a non-profit 'foundation' created by the FANC. It establishes a quarterly report and also publishes an annual activity report of activities to be submitted to its Board.

II.D.5. Relations between the Regulatory Body and the Organisations in Charge of Nuclear Energy Promotion and Use

In Belgium the nuclear power plants are operated by a private operator. It promotes the use of nuclear energy, as does the sector organisation "Nuclear Forum", member of Foratom.

Public organisations that operate nuclear installations or that deal with waste management, such as the nuclear research centre SCK•CEN in Mol, or the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) report to the Ministry of Economic Affairs and to the Ministry of Energy.

As mentioned above, the Safety Authority (the FANC) reports to the Minister of Home Affairs.

The Regulatory Body (FANC and Bel V) plays no part in nuclear energy promotion.

However, the FANC has the mission to "stimulate and co-ordinate research and development activities". It establishes privileged relationships with the public organisations working in the nuclear field, with the scientific research circles and with the international organisations involved." (Art. 23 of the law of April 1994).

II.D.6. International relations

International representations and participations have been optimized between FANC and Bel V, regular information exchange meetings between FANC and Bel V take place, documentation/feedback is systematically shared and common positions are defined.

Belgium signed the main international conventions dealing with nuclear safety and is actively represented in numerous organizations and cooperation programmes.

a) Cooperation at international organisations level

Belgium is a contracting party to the following international conventions:

- the Convention on Nuclear Safety,
- the Joint convention on the safety of spent fuel management and on the safety of radioactive waste management,
- the Convention on assistance in the case of a nuclear accident or radiological emergency,
- the Paris convention on nuclear third party liability and the Brussels supplementary convention, and subsequent amendments,
- the Convention on early notification of a nuclear accident,
- the European ECURIE system,
- the Convention on physical protection of nuclear material.

The FANC and Bel V are also actively involved in other international activities:

At the **IAEA** level, the FANC participate in the Nuclear Safety Standards Committee (NUSSC), the Waste Safety Standards Committee (WASSC), the Transport Safety Standards Committee (TRANSSC), the Radiation protection Safety Standards Committee (RASSC), the Emergency Preparedness and Response Standards Committee (EPReSC), the Nuclear Security Guidance Committee (NSGC) and the INES advisory committee.

In this regard, it can be considered that the FANC and Bel V actively participate in the development and the promotion of the IAEA Safety Standards and will continue these activities in the future.

At the **OECD** level, the FANC also participates in the steering committee of the NEA and in the activities of the following NEA committees: the radioactive waste management committee (RWMC), the Committee on Radiation Protection and Public Health (CRPPH), the Committee on Nuclear Regulatory Activities (CNRA) and the Committee on the Safety of Nuclear Installations (CSNI).

Bel V participates in the activities of the following NEA committees and working groups:

CNRA, CSNI, the Nuclear Science Committee (NSC), the Working group on inspection practices (WGIP), the Working group on operating experience (WGOE), the Working group on fuel cycle safety (WGFCS), the Working group on risk assessment (WGRISK), the Working group on analysis and management of accidents (WGAMA), the Working group on human and organisational factors (WGHOF), the Working group on integrity of components and structures (WGIAGE), the Working group on fuel safety margins (WGFSM), the RWMC Integration Group for the Safety Case (IGSC), the RWMC Working Group on Decommissioning & Dismantling (WPDD), and in various NEA projects.

Bel V is the national coordinator for the incident reporting system (IRS) of the NEA, the incident reporting system for research reactors (IRSRR) of the IAEA, and the fuel incident notification and analysis system (FINAS) of the IAEA.

The FANC has a national coordinator for the International nuclear and radiological event scale (INES), allowing the exchange of information on significant nuclear safety and radiation protection events occurring in all types of industrial facilities.

b) Cooperation at European level

At the European level, the FANC is an active member of the **ENSREG** (European Nuclear Safety Regulators group). Belgian representatives are members of the different working groups set up by ENSREG.

The FANC and Bel V are also members of the **WENRA**, the Western European Nuclear Regulators' Association, and participate in the various WENRA activities and working groups. The Fukushima Daiichi accident significantly impacted the work of WENRA under the impulse of ENSREG, in particular for developing and harmonizing new approaches for safety requirements and emergencies management.

The FANC and Bel V have representatives and actively participate in sub-workings groups of the RHWG (WENRA Reactor Harmonization Working Group) dealing with different technical issues.

In addition, FANC is an active member of **HERCA** (Heads of Radiation Protection Authorities) which brings together 49 radiation protection Authorities from 31 European countries.

Furthermore, the regulatory body (the FANC and Bel V) participates in the European Clearinghouse on nuclear power plants experience feedback, set up to share and analyse international experience feedback at European level.

Finally, Bel V is also an active member of ETSON (the European Technical Safety Organisations Network) and of EUROSAFE and has a cooperation agreement with IRSN.

c) Cooperation at bilateral level

At the bilateral level, several agreements are in force and the FANC has extended collaboration with foreign regulatory bodies.

Amongst others, Belgium has formal agreements with all its immediate neighbors:

- France: various exchanges and agreements exist since the 1980s;
- Luxembourg: an agreement was signed in April 2005 and completed in 2013;
- Netherlands: a Cooperation Agreement between FANC and ANVS was signed on 14 September 2017;
- Germany: a bilateral agreement was signed on December 6, 2016.

Under these agreements, bilateral meetings are held at least on an annual basis.

These bilateral meetings systematically address the operation of nuclear units that may have a transnational impact: in particular Chooz (France-Belgium), Gravelines (France-Belgium); Tihange (Belgium-France-Luxembourg-Germany) and Doel (Belgium-France-Netherlands).

Collaborative activities and exchanges of information are continuous and include:

- exchanges of information of a technical nature. For example, technical files related to the flaw indications in the vessels of Tihange 2 and Doel 3 were transmitted to the German authority and debated between Belgian and German experts;
- exchanges of media information, with the aim of informing and answering the questions of residents and/or local and national elected representatives;
- exchange of information on the of licensing processes of nuclear installations (or of modifications thereof) in progress;
- Cross inspections: A Belgian nuclear inspector accompanies an inspection in a nuclear power plant in the foreign country, and vice versa. The use of national languages imply that these exchanges are more developed with France and the Netherlands;
- exchanges of training: experts from the safety authority participate in training courses organized by the French safety authority, and vice versa;
- cross-participation of experts in national emergency plan exercises, in addition to the necessary collaborations at the level of various local, regional and federal authorities, in particular for the Chooz French power station, considering its proximity to the Belgian border.

With respect to emergency planning and response, the Belgian provincial authorities are also regularly involved in foreign emergency exercises for the nuclear power plants that are close to the Belgian border.

II.D.7. Conclusion

The legal framework and system described in section II.C and II.D offers a solid basis for effective and efficient implementation of regulatory responsibilities and duties.

The Belgian regulatory body has the legal powers and human and financial resources necessary to fulfil its assigned responsibilities including the powers and resources to:

- require the licensee to comply with national nuclear safety requirements and the terms of the relevant licence;
- verify this compliance through regulatory reviews, assessments and inspections; and
- carry out regulatory enforcement actions.

Independence of the regulatory body is strengthened by the legal structure of the FANC and by a clear and well defined relationship with the Government. As extensively discussed during previous review meetings of the CNS, while recognising that a regulatory body cannot be absolutely independent, it was stated and commented that both aspects of independence, de jure and de facto, are essential. It can be found in the literature[1] that those concepts rely on different important parameters like:

- clear safety objectives;
- appropriate financing mechanisms;
- defined accountability procedure and reporting;
- transparency, adaptability to industry and society changes;
- available competence;
- quality assurance;
- management of human resources in the regulatory body;
- access to expertise.

Since September 2001, when the FANC became fully operational, and in further developments of the Regulatory Body, particular attention has been devoted to implement the national structure in accordance with those values and concepts.

[1] INSAG-17 Independence in regulatory body decision making

II.E. Article 9. Responsibility of the Licence Holder

> Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

In view of implementing certain IRRS recommendations, the Law of 15 April 1994 has been amended by the Law of 7 May 2017. Article 28 of this amended law explicitly states the prime responsibility of the licence holder:

"*Art. 28. § 1.*

The licence holder is responsible, in all circumstances, to ensure the protection of the workers, the population and the environment against the hazards or health disadvantages which could arise from the exercise of its practice. This responsibility cannot be delegated."

In addition, the licensee has to comply with the regulations in force dealing with nuclear safety and radiation protection. The legal and regulatory framework expresses in several statements the prime responsibility of the operator for safety.

- Article 5.2 of the GRR-2001 also indicates that the licensee is responsible for complying with the conditions set in the licence. For the nuclear Class I facilities, the licence requires conformity with the Safety Analysis Report. Moreover, the operator must commit himself in the licence application to register with ONDRAF/NIRAS and to conclude with this organisation an agreement on radioactive waste management.
- The operator must also conclude a civil liability insurance (Article 6.2.5 of the GRR-2001); the law of 22 July 1985, which makes the conventions of Paris and Brussels and their additional protocols applicable, and the law of 13 November 2011 set the maximum amount of the operator's liability for the damage at some Euro 1.2 billion per site and per nuclear accident.
- The licensee must organise a Health Physics Department in charge of nuclear safety and radiological protection and must also organise the safety and health at the workplace as well as in the neighbourhood. A detailed description of the duties is given in Article 23 of the GRR-2001 (Article 7- section II.C.3 of this National Report).

Other obligations of the operator include information and training of the workers (including workers not belonging to its own personnel) who might be exposed to radiation, and implementing the policy to limit individual and collective doses (respectively Articles 25 and 20 of the GRR-2001).

The Belgian law also requires that the Regulatory Body permanently controls the proper implementation of the duties of the operator's Health Physics Department. Article 23.1.2.2 of the GRR-2001 specifies a number of specific tasks in that respect.

II.F. Article 10. Priority to Safety

> Each Contracting Party shall take the appropriate steps to ensure that all organisations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

II.F.1. NPPs Licensee Safety Policy and Safety Culture

a) Nuclear Safety policy Declaration

As described in section II.C.4, article 3 of the SRNI requires the licensee to formulate and communicate to all personnel a safety policy with primary importance to nuclear safety and including a commitment to monitor and to continuously improve nuclear safety.

In order to state precisely the nuclear safety policy during operation, the Director-General Manager and the Chief Nuclear Officer (CNO) of ENGIE Electrabel have established and support the following "Policy Declaration on Nuclear Safety", which is included in the Safety Analysis Reports of the nuclear units:

"*In operating our nuclear power stations we attach the utmost importance to protecting the public, the environment and all of our personnel. We therefore support a strong nuclear safety policy that forms an integral component of our operations. We work with our partners and contractors to implement a safety policy based on the following principles :*

Nuclear Safety = top priority

- *We ensure that safety takes precedence over production, at all times.*
- *We integrate safety into all operational processes.*
- *We anticipate new nuclear safety legislation and guidelines, implement them as quickly as possible and comply with them in full.*
- *We develop and promote a high level of safety culture.*

Nuclear Safety = a continuous improvement process

- *We set targets and develop action plans to ensure that nuclear safety measures are continuously improved.*
- *We continuously assess the level of safety of our activities, comparing it to national and international standards.*
- *We analyse and exploit operational experience and research findings in nuclear safety with a view to the timely implementation of feasible safety improvements.*
- *We involve all employees in the continuous improvement process and ensure that they participate actively.*

Nuclear Safety = thorough inspections

- *We maintain a constructive dialogue with the authorities and safety bodies and with all other stakeholders.*
- *We continuously monitor the effectiveness of our safety policy.*
- *We regularly undergo external audits and international benchmarking "*

b) Safety Culture

The ENGIE Electrabel approach for implementing "Safety Culture" is based on four elements, the Nuclear Safety Policy, the Management System, the Global Plan for Nuclear Safety and the Human Performance Programme.

(1) Values and Behaviours promoted by the Nuclear Safety Policy Declaration

The first principle stated in this Nuclear Safety Policy is "Nuclear Safety = top priority".

This Nuclear Policy is posted in many places on the site and at least at the entrance of each building. The document is also integrally copied in the management expectations booklets. During the initial training in nuclear safety, all employees receive the Nuclear Safety Policy document and a specific module is devoted to explaining this policy.

The way to implement the principles defined in the Nuclear Safety Policy is described in the management system. The role, responsibilities and accountabilities of each level of the management regarding nuclear safety are clearly defined by following the INSAG-4 "Safety Culture" from IAEA.

(2) Organizational and individual behaviours supported by the Management System

Below the Nuclear Safety Policy, on a second level, the Management System provides structure and direction to the organization in a way that permits and promotes the development of a strong safety culture together with the achievement of high levels of safety and excellent performance.

The organizational and individual behaviours described in the "Reference Book" and "Governance Nuclear Activities Electrabel" are declined through the Management System. Process owners are in charge to integrate these behaviours into the processes they are responsible for.

The management system promotes a working environment in which staff can raise safety issues without fear of harassment, intimidation, retaliation or discrimination.

The change management covers both the management of organizational changes and the willingness of teams and individuals to adapt to organizational changes that improve safety business performance.

As ENGIE Electrabel strives for continuously developing and improving its employees competence and performance, the Employees Performance Management process involves, in an individual and interactive way with the employee, the definition of objectives with regard to his/her competence development, job performance, the application of corporate values and giving feedback on the employee his/her way of performing.

(3) Electrabel Nuclear Safety implementation plan

The Plan for nuclear safety is an output of the Nuclear Safety Management System. It lays down main objectives of ENGIE Electrabel in nuclear safety for the coming years (from 2016 to 2020). These are aimed in particular at continuously improving the performance and the safety culture.

These objectives are grouped in thirteen themes as following

- Nuclear Safety Culture & Leadership;
- Competence and Knowledge Management;
- Operating experience;
- Operations;
- Chemistry;
- Maintenance;
- Facility Configuration Management;
- Engineering;
- Nuclear Fuel Management;
- Radiation protection;
- Fire Protection;
- Emergency Plan;
- Nuclear Security.

With this Plan, ENGIE Electrabel formally expresses clear objectives to consolidate its safety approach and improve its safety culture.

Regarding Safety Culture & Leadership, the Plan for Nuclear Safety 2016-2020 states objectives in the following areas:

> ***Leadership***: *A strong Nuclear Safety Culture is required in order to achieve zero-incident operation. This means everyone has—and indeed must acutely feel—personal accountability for Nuclear Safety and contribute to human performance excellence. All managers and team leaders are the leading advocates of Nuclear Safety and demonstrate their commitment in word, behaviour and action.*
>
> ***Human Performance:*** *Our nuclear activities depend strongly on human intervention. Striving for excellence also necessitates acknowledging that humans make mistakes. Therefore, it is essential to prevent these mistakes to a maximum extent. Everyone must therefore demonstrate the expected professional behaviours.*
>
> ***Continuous improvement of Nuclear Safety performance:*** *The process of continuous improvement plays a key role in striving for excellence in Nuclear Safety.*

Specific action plans are developed in each entity and organization, with concrete actions to improve the Nuclear Safety culture.

(4) Human performance programme within ENGIE Electrabel

Tihange and Doel power plants have developed a common human performance policy which is based on two approaches:

- A bottom-up approach, which analyses the root causes of events (including the human factor)
- A top-down approach, which relies on human performance tools, safety culture awareness, and tasks observation.

Efficient implementation of the human performance policy in the field requires training and coaching, as well as transparency, trust, and mutual respect (no blame culture).

c) Organisation

Nuclear activities within ENGIE Electrabel are managed on a three level structure:

a) Nuclear Generation level
b) Nuclear Power Plant level
c) Health Physics Department

The departments at **corporate level** playing a major role that are most noteworthy with regard to nuclear safety are:

a) The **Nuclear Generation level**. The Chief Nuclear Officer (CNO) is responsible for the safety, reliability and performance of the Nuclear Plants of Electrabel. The corporate level includes the following departments:
    - Engineering
        - Ensures the development and implementation of the governance of the process "project development and realization" of the nuclear activities, including "Design Authority" and "Configuration Management". This governance is applicable to all projects related to studies and changes and is transposed into local procedures and instructions;
        - Ensures also the performance monitoring of the process "project development and realization". Ensures the control and monitoring of the portfolio of nuclear projects in close collaboration with the sites: coherence with the defined strategy, respect of the planning, priorities;
        - Ensures the central activities related to nuclear fuel management;
        - Ensures the development and the implementation of the governance related to Equipment Reliability, as well as the evaluation of the performance within this field;
        - Develops a special program for the final shutdown and dismantling and decommissioning (D&D).
    - The Corporate department "Nuclear Decommissioning and Radioactive Waste" is active in the following fields:
        - Management of nuclear liabilities, waste and decommissioning;
        - The request for final shutdown of nuclear activities.
    - The Corporate department "Nuclear Fleet performance and Purchasing" is responsible for the following activities:
        - Strategic Asset Management of the nuclear facilities;
        - Process Management.
            - E.g. developing and improving an integrated management system (NGMS) that fosters the continuous improvement of nuclear generation activities.
        - Operational Fleet Management
            - E.g. the periodic evaluation of the performance with respect to Nuclear Safety (Culture), using the self-assessments performed within the nuclear organization.
        - IT applications;
        - Purchasing and Warehousing.
    - The Human Resources Department is located on the corporate level. The activities of Human Resources are mostly focused on the competency development, training and knowledge management of the personnel of Electrabel.

- The Nuclear Security Department reports also hierarchically to the CNO and is responsible for developing and implementing the governance in the following areas:
    - Information security, People security, Physical Security and Cyber security

b) At the **Nuclear Power Plant level**, the organisation is structured in 5 departments:

- The **Maintenance** department is in charge of ensuring the short and long term availability of the installations and equipment. It is also responsible for the management of contractors.
- The **Operations** department is in charge of the safe conduct of the generation process and of the installations.
- The **Continuous improvement** department is in charge of Human Factors and operational Experience activities
- The **Care** department is in charge of surveillance in radioprotection, measurements, protection of the workers (industrial safety), fire protection, environment and safety of the installations (including the setting up and the management of the emergency planning and preparedness). It is the local section of the centralized Health Physics Department (as required by the GRR-2001) and has the appropriate delegation from this department to perform the formal approvals required by the regulations. It ensures also the local independent nuclear safety oversight of the site by e.g. the execution of independent technical checks.

c) The **Health Physics Department (HPD)** is headed by the Chief HSSE & Nuclear Safety.

Besides the Local Health Physics departments on sites (CARE), there is also the Corporate Health Physics Department.

The Corporate HPD department is

- in charge of supporting the increase of the effectiveness of the management of nuclear safety for the nuclear fleet.
- responsible for the Corporate Independent Nuclear Safety Oversight. In this perspective it's performing independent audits and assessments and delivers the operational line – up to the board of Directors – with a current perspective of the Nuclear Safety performance of the nuclear fleet.
- responsible for the governance, oversight and support for the Radiation Protection in Doel and Tihange

d) Monitoring & Assessment of safety performance

In order to ensure optimum efficiency, the internal assessment of Safety is organised into different levels of control where each level corresponds to the different levels of the operational hierarchical line.

The basic elements of the Nuclear Safety Oversight by the line (NSO) and by the independent line (INSO) are schematically depicted in the figure here below:

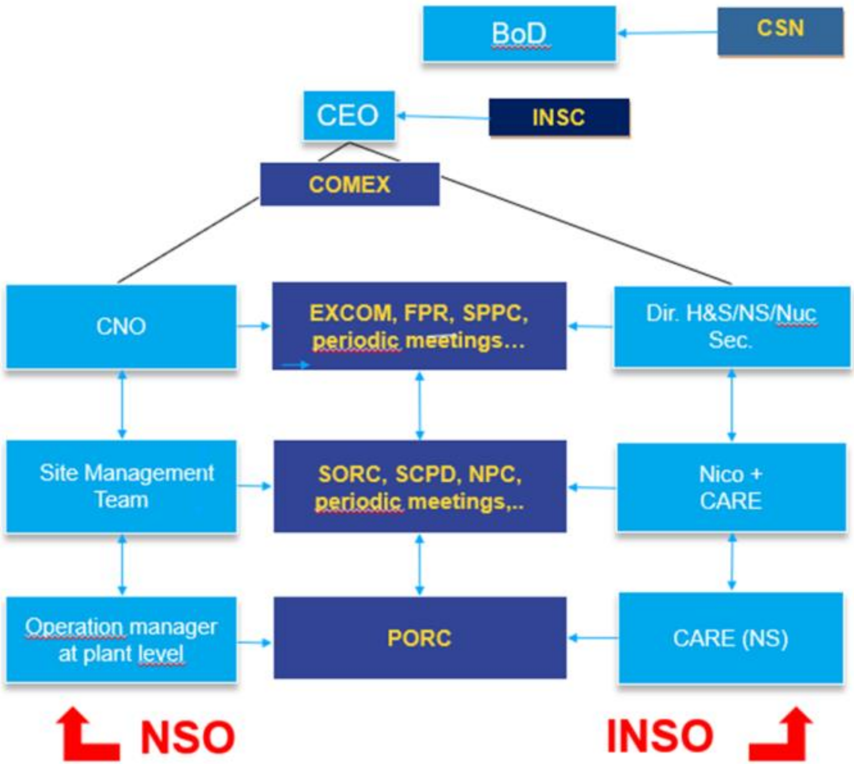

Figure 9 : Internal Safety Assessment

The left-hand side of the figure shows the operational line, which has the final responsibility for nuclear safety.

NSO: In line with the internal governance, the operational line executes its Nuclear Safety Oversight at least via:

- The yearly Process-Reviews, Self-Assessments, Management Reviews and Functional Area Health Reviews. These are conducted by the Process Owners, Functional Area Managers and Fleet Managers (in support of the line management).
- The follow-up of the NS performance via the different NS Committees. E.g.
    - On Plant level: the Plant Operational Review Committee (PORC).
    - On site level: the Site Operational Review Committee (SORC), the Site Contract Performance Dialogues (SCPD), the Nuclear Project Committees (NPC).
    - On fleet level: Executive Committee (EXCOM and COMEX), Fleet Performance Reviews (FPR), Strategic Project Committee (SPPC) and the Nuclear Safety Committee (CSN).

The right-hand side of the figure relates to the Independent Nuclear Safety Oversight **(INSO)**, which has the task of providing **independent** oversight of nuclear safety, so executed by people, which are independent from the operational line (or the HPD). This independent Nuclear Safety Oversight is mainly performed on three levels;

- The **Local INSO** (by the local HPD departments or CARE departments) by challenging the daily operations, executing technical reviews and independently analyzing and approving the safety assessments of modifications, managed on site.
- The **Corporate INSO** (by the Corporate HPD department) by executing in depth process reviews, independently analyzing and approving the safety assessments of modifications managed on Corporate level, performing QA-Audits and challenging the NSO-assessments.
- The **external INSO** (by the Independent Nuclear Safety Committee or INSC). This committee is made up of various external members and members of the internal INSO line. The INSC analyses the activities, events, projects and processes having a major

impact on nuclear safety and reports its conclusions to the ENGIE Electrabel management team, the CEO and the Board of Directors.

The figure also shows the NS oversight committees (PORC, SORC, FPR's…) for the various levels. Members of the INSO-line participate also to these committees, and challenge the NSO decisions in these committees, and present their own nuclear safety messages and conclusions.

II.F.2. Research Reactors

The general management of SCK•CEN published a safety and security charter stating the importance of safety for the operation of the installations. The charter also promotes a positive attitude towards safety culture. Additionally, attention is given to security and physical protection aspects.

These general statements are further put into practice by a number of actions. A short training on the aspects of safety culture was given to all members of the personnel. The aim of this training is to convince the personnel that reporting of unusual or unsafe situations, including those as a consequence of own errors, is an important way to prevent accidents. For BR2, a system to report these events (technical and non-technical) already existed and is now included in the general registration system of SCK•CEN. This is a completely open system. Every member of the personnel can introduce a report without restriction. The reports are discussed during the daily operators meeting and an action is defined if necessary. The system is centralized by the internal safety services.

Another point of attention is the learning from operational experience feedback (OEF), both from internal and from external events. Personnel are encouraged to report information with a potential interest for others, regardless whether these are incidents or good practices. For the external OEF, special attention is paid to the IAEA incident reporting system for research reactors. Information from incidents from power reactors is used insofar the subject is applicable to BR1 or BR2.

The training of the personnel also included risk analysis, for use during the preparation of a task or during the execution of the task. Operating procedures, especially the procedure for executing non-standard tasks, include a risk analysis. In case of an incident, an investigation on the causes is executed. The cooperation of the operators is solicited. Everyone is expected to add his information, which will be treated blame free.

A last important action is to keep the knowledge of the installation. The SCK•CEN has an operation history of more than 60 years, which means that people involved in the design and building of the installations are no longer available. It is considered very important to keep all documentation about the installations in good condition in such a way that it is readily available. A special action was initiated about this issue.

In order to coordinate all these actions on safety, an integrated management system has been developed and implemented, based on the IAEA Standard GS-R-3 (The Management System for Facilities and Activities). The development of this system will continue in the next years as more and more processes will be added to the system.

II.F.3. Regulatory Body

The FANC is responsible (amongst other duties) for the supervision and control of all the activities concerning radiological protection and nuclear safety.

Radiological protection, and implicitly nuclear safety, is emphasised in the general principles of the GRR-2001. However, special emphasis has been put on safety by the FANC.

End 2013, the FANC established the governance document GD006-01: "*Missions, activities and reporting of the section in charge of the surveillance of Nuclear Facilities*". This document is quite explicit regarding priority to safety, and lists the following specific missions:

1. *Ensure that (nuclear) facilities have an adequate level of safety, taking into account the current standards for nuclear safety and radiation protection, in their design, during their operating phase and their decommissioning and dismantling. This is achieved with the full cooperation with Bel V, respecting the role and responsibilities of each other.*
2. *Ensure that all events having a potential impact on nuclear safety or on radiation protection are properly managed and contribute to the process of experience feedback at national and international level.*

3. *Ensure that people in charge of Health Physics Control in nuclear facilities, including on behalf of Bel V, have the necessary skills and knowledge to ensure nuclear safety and radiation protection, and that these skills and knowledge are maintained at a high level at all times.*
4. *Contribute to the establishment and / or to the improvement of national and international regulations by proposing useful and adequate requirements and rules to continuously improve the level of nuclear safety.*
5. *Exchange of a correct, independent and transparent technical information with all stakeholders to improve the level of nuclear safety and radiation protection.*

In application of these basic principles, since January 2009, FANC and Bel V develop a common strategy for inspections and control of the nuclear installations. This strategy guarantees a more integrated approach in the field of nuclear safety and radiation protection. A 3 year programme is defined. An annual planning for inspections is established, based on this programme and is communicated to the licensees. A revision of the programme is foreseen each year, to take into account experience feedback from the preceding years.

On the basis of its large inspection experience as well as of its well-established know-how in collecting and interpreting operation feedback data, Bel V has over the years developed an inspection and safety assessment strategy aimed at the assessment of how the licensees manage safety, with specific emphasis on the implementation of the GRR-2001 and of the licences of the various installations. This strategy contains the implementation of a permanent monitoring of the licensee and of conformity checks of the installations, general objectives and an inspection programme with various types of inspections. This strategy is evolving with time and safety concerns (e.g. human and organisational performances) and is supported by strong programmes of expert initial training and retraining, of operating experience data collection and analysis and of specific research and development activities.

This strategy is imbedded in the various processes of the ISO-9001:2015 quality system of Bel V (certification obtained in the beginning of 2018), which is based on expert assessment and judgement. The system allows a clear definition of responsibilities and a better tracing of the performances.

II.G. Article 11. Financial and Human Resources

1) Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.
2) Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety related activities in or for each nuclear installation, throughout its life.

II.G.1. NPPs

a) Operator's Financial and Human Resources to use the Installation throughout its Industrial Life

The main activities of ENGIE Electrabel are the generation and commercialisation of electricity and gas in Europe. In Belgium, ENGIE Electrabel is the owner of the twin units 1 and 2 (100%) and the units 3 and 4 (89.8%) of Doel, and of the unit 1 (50%) and of the units 2 and 3 (89,8 %) in Tihange. Belgium's nuclear generating units account for some 40% of electricity production in Belgium.

About 2200 people (about 300 at corporate level and the remaining equally distributed on the NPP sites) are devoted to nuclear power plant operation among Electrabel's total workforce in Belgium of around 4300. The business unit ENGIE Benelux, of which ENGIE Electrabel is a part, has around 16700 employees in Belgium. In September 2002, the company Elia System Operator was appointed by the Belgian Government as the Manager of the electricity distribution network. This activity is now completely separated from the activity of electricity generation. Electrabel has signed specific contracts with Elia. In accordance with the legislation on deregulation of the electricity sector in Europe, all distribution activities in the three regions of Belgium have been separated and turned into independent companies.

The ENGIE group also has an Engineering division, Tractebel ENGIE, which is the Architect-Engineer of the Belgian nuclear power units (and of most of the fossil fired plants) and which houses know-how accumulated over fifty years of nuclear technology, which started with the construction of the first research reactors at the SCK•CEN.

b) Financing of Safety Improvements during Operation

Major safety improvements to the Belgian nuclear power stations emanate from the periodic safety reviews (ten-yearly) and are financed through annual provisions (1/10th each year). Cost of specific projects and for replacement of aged or obsolete components are amortized on the remaining lifetime of the concerned power plant.

c) Financial and Human Provisions for Future Decommissioning and for Management of the Waste produced by the Installations

The existing mechanisms are described in the Belgian report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. More details can be found in that report, available on the FANC and IAEA web sites.

d) Rules and Requirements for Qualification, Training and Re-training of Personnel

The Safety Analysis Report (chapter 13) deals particularly with personnel qualification, training and re-training. Qualification of the personnel is inspired from the ANS 3.1 standard, though adapted to the Belgian educational system. The Safety Analysis Report defines the level of qualification corresponding to each of the safety-related functions. It does not state the individual qualifications of each person in the organisational chart. However, proof of qualification of all the operating personnel is available to Bel V. The functions and qualifications prescribed by the US regulations are transposed in function of the educational system structure and curricula existing in Belgium.

The training programmes are defined in the Safety Analysis Report, which includes a "function-programme" correlation chart. Chapter 13 of the Safety Analysis Report lists exhaustively all posts for which an authorization is required. This authorization is based on the positive opinion expressed by an Assessment Committee, which examines the candidate's knowledge. This qualification is reviewed every two years or when an authorized person has ceased for four months or more to perform the function for which he/she was qualified. It is renewed on the condition of, among other, a favourable advice of the Assessment Committee on the basis of the individual's training and activity file.

Bel V is member of the Assessment Committee, with veto right.

A knowledge re-training programme for all authorized personnel is defined in function of the occupied position. The contents of this programme which is discussed with Bel V, is essentially operation-focused and includes, among other, a refresher course regarding the theoretical and practical knowledge (two weeks per year), training on the full-scope simulator (two weeks every two years) and, in teams, a review of the descriptions of the different systems (two weeks per year).

The SRNI-2011 requires that the Licensee identifies in a systematic and documented way, the needs with regard to the qualification and training of personnel executing safety-related activities

The GRR-2001 requires an annual retraining of the whole personnel on the basic rules of radiological protection, including the good practices for an efficient protection and a reminder of the emergency procedures at the work site.

e) Training at ENGIE Electrabel

(1) Electrabel training policy

The Electrabel policy statement on competency development and personnel training recognizes that the training of personnel and the continuous development of their skills are essential for the on-going safety and optimal performance of both the on-site plant staff and the installation.

Through this policy, the Doel and Tihange NPP management ensures that every employee receives appropriate training and only qualified personnel is assigned to tasks involving risks.

Every new employee follows an initial training programme that is aligned with their job description.

Every staff member of ENGIE Electrabel has an individual development plan. The content and implementation of this plan follows a four-step approach:

1. Analysis of the gaps between the competences required and the level as assessed by the individual and their manager
2. Creation of individual development plans
3. Implementation of development actions
4. Coaching and monitoring, evaluation and feedback

Managers regularly check that the aims of the training courses are being met and suggest improvements. To do so, they participate in training, perform verifications and/or gather feedback and evaluation results.

Article 6.2 of SRNI-2011 (WENRA Reference Level D.2.1) states: "Only qualified persons that have the necessary knowledge, skills, and safety attitudes shall be allowed to carry out tasks important to safety. The licensee shall ensure that all personnel performing safety-related duties including contractors have been adequately trained and qualified". All employees in question, including contractors, have obtained a competence pass ('Bevoegdheidsverklaring' in Doel, 'Passeport Métier' in Tihange), which shows that they have received adequate training and are fully qualified. The acquisition of competences during a training program is formally checked.

Training Facilities:

Each site has a Training Centre (on site or off-site) with a number of training facilities. It includes:

- A field simulator for work practices and human performance tools (the Human Performance Simulator);
- A room for hands-on training, for instance on the operation of pneumatic valves and controllers;
- A room for the initial training of operators featuring a large number of demonstration tools;
- Simulators (full-scope or multifunctional): Both Doel and Tihange have full-scope simulators.
- In Tihange, there are 2 full-scope simulators, one is a precise replica of Tihange Unit 1, and the second one of Tihange Unit 2. Extensions such as additional hardware panels and screens have been added to the equipment of the Unit 2 simulator in order to provide the best possible training of Unit 3 operators.

A third simulator, with a non-replica man-machine interface, is used to illustrate specific aspects related to regulations, primarily through the projection of images. The three units being simulated on this "Multifunction simulator", it suits as a complement for the training of unit 3.

- Doel has two full-scope simulators: these are precise replicas of Doel Unit 1 (and thus also of Unit 2) and unit 4. The full-scope simulator of Unit 4 can be used in Unit 3 mode.

(2) Training Requirements

The training cycle is subdivided into two parts:

1. Initial safety training;
2. Refresher safety training.

Initial safety training includes course on nuclear safety, health and safety and environmental issues and must be completed by each NPP employee before they start their job. The initial training programme is tailored to the nature of function that will be occupied by the employee. Three levels have been defined accordingly.

Refresher safety training is given on an annual basis and is mandatory. It keeps employees informed about changes and operating experience in the areas of nuclear safety, industrial safety, radiological protection, environmental safety, human performance and management expectations. For technical functions, an additional refresher course has been developed but runs over 5 years.

(3) Training programs

Training programs have been developed for Operations personnel, Maintenance personnel, technical and support personnel and management and supervisory personnel.

More details are given below on the training programs for Operations and Maintenance personnel:

Operations personnel:

Members of staff who are directly responsible for the operation of the reactor units must receive an operator's authorisation. This certification must be obtained before the person is nominated for a position.

The training programme for authorised operators (Shift Supervisors and Control Room Operators) is in line with legal requirements. It comprises a basic training package, training in emergency procedures, and complementary training courses. The training programme includes:

- Control room training under the supervision of a Shift Manager;
- Hands-on training through integration in a team of Shift Supervisors and/or Control Room Operators;
- Simulator training given by the Operations Support Service;
- Training on specific installations, covering aspects such as firefighting and first aid.

The periodic retraining of authorised operators also meets legal requirements. It is established by the Operations Service and comprises the following elements:

- One week refresher course, per year, in classroom and in other installations suited for exercises, in line with the function;
- Two week internal team training, per year, under the supervision of the Shift Supervisor;
- Two weeks of full-scale simulator training, per year, given by the Operations Support Service.

As with certified operators, the training program for Field Operators is in line with legal requirements. It also comprises a basic training package, training in emergency matters, and complementary training courses. The training program includes:

- Classroom training under the supervision of a Shift Supervisor. This training covers thermodynamics, electrical and electrotechnical principles, systems and components, circuits, instrumentation, and safety principles;
- Hands-on training through integration in a team of Field Operators;
- Training on specific installations, covering aspects such as firefighting.

The annual retraining programme of Field Operators is established by the Operations Service and is based on a two day refresher course in a control room and in other installations suited for exercises, in line with the function.

Maintenance personnel:

After the initial generic training course, future technicians follow a specific training programme. This programme specifically addresses mechanical, electrical and I&C technicians. It lasts approximately one year. Other team-specific training courses are provided in addition to this programme.

The switch from a technician to a first technician and further to team leading function requires completion of specific training courses.

(4) ENGIE Nuclear Training Programme

In 2005 GDF-Suez decided to develop its nuclear activities and created a dedicated Nuclear Activities Division. This Division is now called ENGIE Nuclear Development (DDN). One of its missions is to:

- Anticipate needs in junior engineers (max. 2 years of professional experience) for replacing retiring managers and for staffing new nuclear projects
- Build up a Nuclear Training Programme (NTP):
    - **NTP Junior programme**: for **junior engineers** by giving them a general view on all the aspects of the nuclear activities and to help them build a strong network through the ENGIE Group.
      This programme (400 hours) consists in different types of trainings in order to improve 3 types of competencies (métier – behavioural – functional)
    - **NTP Majors programme**: a similar training programme of three weeks was launched in April 2010 for senior engineers coming from several entities of the Group, but having no specific nuclear knowledge. This will enable them to subsequently reinforce the nuclear activities of the Group and their comprehension.
    - **NTP Support programme**: a training programme of two days for managers in support departments like Legal, Finance, HR, Procurement to explain the specificities of the nuclear energy sector. During this training, trainees also better understand their contribution to nuclear safety.

(5) Contractor Training and Qualifications

Contractors are responsible for the training of their own personnel. Nevertheless, ENGIE Electrabel shall ensure that all contractors performing safety-related duties have been adequately trained and qualified". All contractors in question have obtained a competence pass ('Bevoegdheidsverklaring' in Doel, 'Passeport Métier' in Tihange), which shows that they have received adequate training and are fully qualified. The acquisition of competences during a training program is formally checked. Moreover, training in radiological protection is legally required and is made specific to the site where they will work. They must pass an examination at the site before they are allowed to the work place. An intensive training programme for all personnel of contractors has been put in place, focussing on nuclear safety and work in a nuclear environment. The successful completion of this training is mandatory before being allowed to work on the site of the nuclear power plants.

A general training programme is set up for all contractors. This general training programme focuses on safety culture (both nuclear and industrial safety), is carried out partly on a theoretical basis and partly on a hands-on approach using the Human Performance Simulator (see also II.H.1.d). It covers the 4 tools for the effective application of the human performance principles, as the adherence to procedures (stressing the need for a strict respect of prescribed steps), the interrogative attitude (the principle to correctly apply the instructions using the STAR methodology: Stop – Think – Act – Review), the use of secured communication and the use of the pre-job briefing methodology.

II.G.2. Research Reactors

a) Financial resources

The SCK•CEN, the Belgian Nuclear Research Centre is a "Foundation of Public Utility" (FPU) with a legal status according to private law, set up according to the law on non-profit organisations, under the supervision of the Belgian Federal Minister in charge of Energy. From the first of January 2005 the SCK•CEN, like any other non- profit organization has to apply the principles and rules prescribed by Belgian accounting rules. The turnover and the operating profit of the previous years are defined in accordance to this law. The adequacy of the SCK•CEN's financial system and internal controls is assessed by an external auditor. According to the safety and security charter, the management hereby is committed to provide all necessary financial means to enhance safety and to ensure all required security measures.

The future cost for dismantling is covered by funds. With respect to these technical liabilities, the following rules for funding apply. All dismantling costs for installations built and in operation before 1989 are covered by a special 'Technical Liabilities Fund', which is administered outside the SCK•CEN. All new technical liabilities after January 1989 are financed by the SCK•CEN by means of setting up the necessary provisions. The total liabilities are periodically reassessed and total amounts have to be available at the moment of dismantling and decontamination. The necessary financial means are funded by means of annual government grant and by revenues from contract research and services to third parties. SCK•CEN is consolidated in the national accounts of Belgium and also has to comply with the accounting standards of ESA 2010[2].

b) Human resources

The minimum requirements for operating personnel are detailed in the safety analysis report both for BR1 and BR2. These requirements are the necessary education and training of the personnel. The minimum number of personnel necessary for operating the reactor is also specified. For BR2 additional requirements for training are defined. Each reactor operator has to receive two weeks training every year. The initial authorisation as a reactor operator is given on advice of a committee, in which the Health Physics Department and Bel V are represented with veto power. Reauthorisation is necessary every three year or after a longer period of non-activity as an operator. The requirements for BR1 personnel are less formalized. The appointment of the BR1 reactor manager has to be confirmed by the health physics and safety department. The training of the operators is defined by the BR1 reactor manager case by case. This is acceptable due to the limited number of operators for BR1.

II.G.3. The Belgian education programme in nuclear engineering

As a joint effort to maintain and further develop a high quality programme in nuclear engineering in Belgium, the Belgian Nuclear higher Education Network (BNEN) has been created in 2001 by six Belgian universities and the SCK•CEN.

In the framework of the new architecture of higher education in Europe, the BNEN created a 60 ECTS "Master of Science in Nuclear Engineering" programme. To be admitted to this programme, students must already hold a university degree in engineering or equivalent education.

The BNEN programme is given in the table below:

[2] The European System of Accounts (ESA 2010 or ESA) is an internationally compatible accounting framework for a systematic and detailed description of a total economy (that is, a region, country or group of countries), its components and its relations with other total economies

	ECTS[3]
Compulsory modules	**31**
Introduction to nuclear energy	3
Introduction to nuclear physics	3
Nuclear materials	3
Nuclear fuel cycle	3
Radiation protection	3
Nuclear thermal-hydraulics	5
Nuclear reactor theory	6
Safety of nuclear power plants	5
Elective modules (9 ECTS to be chosen from the list below)	**9**
Advanced nuclear reactor physics and technology	3
Advanced nuclear materials	6
Advanced radiation protection & radiation ecology	3
Advanced courses of the nuclear fuel cycle	3
Nuclear and radiological risk governance	3
Advanced course elective topic	3
Master thesis	**20**
Total	**60**

Table 6 : BNEN Curriculum

More information can be found on the BNEN web site: http://bnen.sckcen.be

In addition to the BNEN Master-after-Master academic programme, the SCK•CEN Academy also organises the Radiation Protection Expert course (120h) in collaboration with the Hasselt university: http://academy.sckcen.be/en/Academic_courses/Radiation_Protection_Expert .

For professionals in nuclear industry, healthcare, research organisations and governmental organisations, the SCK•CEN Academy also offers customized training courses on all topics that are subject of the R&D portfolio of SCK•CEN:

- radiation protection: initial (9 days) and refresher courses (5 days) in radiation protection for NPPs in Doel and Tihange
- nuclear reactor technology: 90h course for reactor operators of NPP Doel and two-week contribution to the Nuclear Training Programme of ENGIE Electrabel
- nuclear emergency management: participation of NPP personnel in these open courses which are organized on an annual basis

At European level the European Nuclear Education Network (ENEN) (www.enen.eu) has been established as an international association of 67 member organisations including universities and other stakeholders (industry, regulators and research centres) and is strongly supported by the European Commission. BNEN is the Belgian pole of this network. Students registering to any of the participating institutions are offered the opportunity to coherently take a part of their basic nuclear education at different places in Europe while cumulating credit units.

[3] ECTS stands for "European Credit Transfer and Accumulation System", 1 unit corresponds to approximately 10 learning hours

II.H. Article 12. Human Factors

> Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

Accounting for human factors at the design stage is discussed in Article 18 of the present National Report. The text below is centred on human factors during the operational period of the power plants.

II.H.1. NPPs Human Performance Programme

As already mentioned in article 10, the human performance policy is based on two approaches:

A bottom-up approach

- Everyone is encouraged to report suggestions and anomalies or human errors in a software application (OESAP). These reports are used to improve the performance.
- Root cause analysis of errors and malfunctions cover both technical aspects and human factors in order to reinforce defence barriers. Such an analysis therefore:
    - Highlights and explains all deviations linked to an event;
    - Identifies the real and potential consequences of these deviations;
    - Analyses the direct, apparent and root causes of the event;
    - Defines the corrective actions to be implemented to avoid recurrence of the event;
    - Second layer HU analysis.

A top-down approach

- The top-down human performance approach is based on leadership, values, change management and organisational behaviour.

The focus is to ensure the integration of good safety behaviour and use of human error reduction tools (HU tools):

- Management expectations: The HU tools are embedded in the Management Expectations booklets, specific procedures and execution aids (e.g. pre-job documents, work permit, observation forms, etc.). Films were made to clarify specific expectations (e.g. for alarm management in the control room).
- Tasks observation: Managers and supervisors frequently conduct task observation in the field in order to:
    - Reinforce management expectations, including human performance, by valuing the appropriate behaviour and correcting deviations;
    - Identify and correct deviations;
    - Reinforce contacts with the field.
- Communication: Specific HU communication is achieved by using electronic Public Address display, newsflashes, films, magnetic posters and during training sessions.
- Training: Workshops and training for leaders and teams have been delivered to enhance leadership and coaching skills. After the initial Human Performance training, the HU training was embedded into initial training, control room training and field simulator training. HU also became part of the improved self-assessment approach, making the link with operating experience thus closing the learning loop (with special attention for using observation results).
    - "HU Clock" (reset of the day count, each time an event is caused by human error and two performance indicators (HU Index and HU Ratio).
- Specific actions plans to improve the Human Performance: For instance:
    - From 2016 to 2018 a comprehensive CORE-action plan was established and executed. One of the main purposes of this action plan was to decrease the amount of human errors during the execution of the operational tasks (e.g. by increasing the questioning attitude, self-checks, improving the use of the procedures, reinforcing the expectations in the field, giving and following awareness trainings,…).

Each operational department also has also its own dedicated action plan to increase the human performance.

a) *Use of human error reduction tools (HU tools)*

The focus is to ensure the integration of good safety behaviour and use of human error reduction tools (HU tools):

- Situation awareness: includes workplace screenings, questioning attitude, anticipation and time-outs (pause before starting an activity if anything is uncertain).
- Self-control: revolves around the STAR concept of 'Stop-Think-Act-Review'.
- Pre-job briefings: interactive dialogues that cover the task to be carried out – taking into account experience, risks and error precursors, as well as the worst-case scenarios. In some cases, Pre-job briefings are referred as "Tool box meetings".
- Post-job debriefings: reporting that a task is completed, notifying any abnormality, reviewing the paperwork fully and highlighting lessons learned (input for operating experience and optimization of procedures).
- External verifications on practices: peer checks, concurrent and independent verifications to safeguard quality and safety.
- Effective communication: taking into account basic principles of good communication (such as informing all parties involved), favouring direct dialogues, securing understanding by three-way communication, phonetic alphabet.
- Careful decision-making: includes anticipating, evaluating options, checking assumptions, conservative decision taking and thinking as a team.
- Intelligent use of procedures: making sure that procedures are correctly understood and applied in practice. In case of doubt, one stops and changes are only made after appropriate consultation and red-marking.

b) *Operating experience feedback*

Operating experience feedback is communicated as extensively as possible and integrated as soon as possible into the relevant training courses. Yellow stickies exercises are used periodically within the teams to define from the OE reporting database the actions for improvement.

c) *Task observations*

In addition, task observations are held in order to:

- Reinforce management expectations, including human performance, by valuing the appropriate behaviour and correcting deviations.
- Identify and correct deviations.
- Reinforce contacts with the field.

Programs are ongoing to increase the effectiveness of these task observations. For instance, managers and leaders are receiving different trainings and coaching to perform these task observations or 'support visits' in the field more effectively.

d) *Human Performance Simulator*

Tihange and Doel NPP are equipped with their own "human performance simulator". This training facility is an excellent training tool to model safety behaviours. This training model comprises essentially all important parts that are typical for an intervention in a nuclear installation like:

- A dressing room: to prepare entrance and exit of a nuclear zone with appropriate suits, including clothes, dosimeter, and contamination checking before and after intervention.
- A briefing space: where teams can prepare preliminary works or give some orders before an intervention exercise.
- A tool store: to store necessary tools, or spare pieces.
- A radioprotection room: located next to the entrance of the nuclear zone, where staff can find a radioprotection supervisor, and contamination monitors.
- An electrical room: local with electrical board and batteries.
- A control room: with control panel from which staff can operate equipment.
- A mechanical room: where mechanical equipment such as pumps, valves, tanks, etc… is present.

Trainees enhance their safety attitudes and behaviour by responding to simulated problems and changing conditions being encountered during an intervention. Different scenarios of intervention have been developed for training purposes. Trainees are recorded on video and followed by instructors to coach them and improve their safety behaviours.

Figure 10 : Human Performance Simulator

II.H.2. Research Reactors

In 2007 a number of events occurred at the SCK•CEN, mostly at BR2, which indicated weaknesses in safety culture. The SCK•CEN reported these precursor events to the authorities and ordered an internal and external audit on safety culture. Based on both audits, an action plan for improvement of safety culture was launched. The main themes of the action plan concentrated on safety training, knowledge management and organizational aspects. The content of the action plan was discussed with the authorities and a regular follow-up was foreseen. The action plan was completed in 2012.

Organizational aspects

Training programmes and knowledge management are centralized in one service, the expert group communication, education and knowledge management. Training programmes with safety aspects are defined in cooperation with the health physics and safety expert group.

Training

Most of the training is given in-house, but external training is possible. For BR2 operators, two weeks training per year is foreseen. Training on a simulator, as is the practice in power plants is not possible for BR1 or BR2. However, the activities of the BR2 reactor requiring at least 5 to 6 starts per year and the measuring program requiring critical approaches enable the personnel to train on the job.

During the last years, practical training for the BR2 operators was given at foreign research reactors (AZUR in Cadarache, France and the TRIGA reactor of the technical university of Vienna, Austria). Training requirements for personnel of BR1 are less formalized and are evaluated in the current periodic safety review. The number of operators for BR1 is very limited and the reactor is not operated outside normal working hours nor during holiday periods

Knowledge management

For an organisation with an operating experience of more than 50 years, knowledge management is an important issue. People present at the start of the installations are no longer available. Being a research environment, a number of modifications are made and new experiments are set up. An action is taken to collect all design documentation of the installation and make it readily available. For persons with a key function a backup must be available, with an equivalent knowledge or with capacity to get this knowledge quickly.

II.H.3. Safety Culture Observations by the Regulatory Body

The Federal Agency for Nuclear Control and Bel V have jointly developed and implemented a Safety Culture observations process. Observations are performed by Bel V's inspectors or safety analysts during any contact with a licensee[4]. These observations are filled in an observation sheet aimed at describing fact and context issues. These observations are linked to Safety culture attributes based on IAEA standards[5].

On a monthly basis the "Safety Culture coordinator" within Bel V analyses observations (with a quality of description and classification perspective) and gives a feed-back to the observation maker. In case of an important SC discrepancy, a direct reporting to the licensee could be considered.

On a quarterly basis, the "Safety Culture coordinator" provides a mainly quantitative synthetic report. The aim of this report is to identify early signs of problem. Then, it could be decided to analyse a plant's performance more deeply in order to understand the underlying causes of a problem or to focus inspections on specific dimensions.

On an annual basis, the "Safety Culture coordinator" provides a detailed report on the observations (with a safety perspective). The aim is to identify persistent signs of problems or good practices. These statements feed the next annual inspection programme. A synthesis is presented to the licensee. The discussion objective is to be sure that the licensee understands the regulator's concerns.

In terms of regulatory body evaluation, Safety Culture observations are then central pieces of a broader oversight process trying to identify and analyse Safety Culture dimensions.

A deep process assessment has been conducted in 2015 (after 3 years of application) and yearly evaluations of the process are performed as well. The process is now fully operational.

[4] Inspections (routine, topical and reactive), meetings with licensees, training activities, formal and informal discussions with plant staff at various levels, document review, review of event reports (including low level) and corrective actions implemented, observation of activities and conditions in the field…

[5] IAEA/CNCAN (2010). *Guidelines for Regulatory Oversight of Safety Culture in Licensees' Organisations*.
IAEA/BNRA (2011). *Guidelines for Regulatory Oversight of Safety Culture in Licensees' Organisations*.

II.I. Article 13. Quality Assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

II.I.1. NPPs

a) Background

As the USA safety rules were applied for the 4 most recent Belgian units as early as at their design stage, 10 CFR50 Appendix B requirements were adopted for these units, as well as the ASME code quality-assurance stipulations for pressure vessels. Also taken into account were the 50-C-QA codes and the resulting safety guidelines (including 50-SG-QA5) developed in the scope of the IAEA's NUSS programme.

At the time of putting into service the Doel 1 & 2 and Tihange 1 units, i.e. 1974-1975, that level of quality-assurance formalism was not yet required. However, during the 1st periodic safety review of these units, the request was formulated to apply to them the same quality-assurance rules as were applied to the more recent units: accordingly, any new installations, modifications, repairs and replacement at the earlier units were from 1985 on made consistent with the formal QA requirements.

The responsibility for applying the quality assurance programme is assumed by the operator who subcontracts the related tasks to his Architect-Engineer during the design and construction phases of the power stations, up to and including their start-up tests.

While following the evolution of the international practices, ENGIE Electrabel evolved from its quality assurance system during operation to a quality management system, in September 2006. This management system includes the previous applicable quality assurance system. The elaboration of the quality management system was based primarily on a general safety requirement published by the AIEA (GS-R-3: "The management System for Facilities and Activities", 2006).

The Nuclear Safety management system of ENGIE Electrabel was updated in 2017. In this update, a clearer description of the roles and responsibilities related to the Governance, Oversight, Support and Performance (GOSP-model) for the different processes and functional areas, important for the Nuclear Safety, is given. The improvement cycle for the different processes and functional areas is reinforced as well.

The term "management system" encompasses the initial notion of "quality control" and its extension to include "quality assurance" and "quality management". A management system is a set of interdependent or interactive elements aimed at establishing policies and objectives, and which helps achieve objectives in a safe, efficient and effective manner.

The management system for nuclear safety is described in chapter 17 of the Safety Analysis Report which deals with the design and construction phases, followed by the operation period. As there is no unit under construction at present in Belgium, emphasis is put on how the integrated management system is applied during operation.

b) Electrabel's global approach

The principal goal of Electrabel's management system is to ensure and to improve safety at Electrabel's Doel and Tihange power stations through a common approach and via plant-specific approaches.

To fulfil its mission and achieve its objectives, ENGIE Electrabel establishes, implements, assesses and continually improves a management system that meets the following basics:

- Nuclear Safety is the overriding priority within the management system, taking precedence over all other considerations;
- It fosters the development of, and promotes the improvement of, a strong Nuclear Safety culture by improving behaviour and attitudes both among individual workers and line management;
- It identifies and integrates coherently all requirements that are applicable to its activities and processes, especially as regards Nuclear Safety, Quality, Nuclear Security, Health and Safety and Environmental protection.

- It is based on the identification, development, implementation, assessment and continuous improvement of the processes needed to achieve the goals and meet all requirements applicable to ENGIE Electrabel.
- To deploy appropriately its resources, ENGIE Electrabel implements the requirements of its management system following a graded approach.

The implementation of this management system allows ENGIE Electrabel to:

- Improve its Nuclear Safety performance through the planning, monitoring and control of its safety-related activities;
- Ensure that Quality, Nuclear Security, Health and Safety, Environmental protection requirements and Economic considerations are not considered separately from Nuclear Safety, to help preclude their possible negative impact on Nuclear Safety
- Describe the planned and systematic actions necessary to provide adequate confidence that it conforms to all its applicable requirements;
- Allocate appropriate resources to carry out its activities and provide the countermeasures to be put in place in order to offset any process or activity failures.

The effectiveness of the management system is monitored and measured to confirm the ability of the processes to achieve the intended results and to identify opportunities for improvement.

Opportunities for the improvement of the management system are identified and actions to improve the processes are selected, planned and recorded.

Actions for improvement are monitored through to their completion and the effectiveness of the improvement is checked.

c) Applicability

The integrated management system applies to any safety-related structures, systems, components as well as to any activity that may affect nuclear safety. It applies also to the safety-related activities or process affecting nuclear safety, e.g. human performance, organisational performance, safety culture, radiological protection, radioactive waste management, fire detection and protection, environmental monitoring, nuclear fuel management, emergency intervention and site security.

These structures, systems and components and activities are known as safety-related. There are identified in the Safety Analysis Report of each unit.

d) Key documents

ENGIE Electrabel's management system for Nuclear Safety is described in a number of documents that move downwards from broad principles towards technical specifications and daily practices:

- Chapter 17.2 of the FSAR
- The Policy Manual or the Nuclear Generation Management System Reference Book
- Governance Nuclear Activities ENGIE Electrabel
- Execution documents

The "Reference Book" and the "Governance Nuclear Activities ENGIE Electrabel"

The "Reference Book" is the cornerstone of the ENGIE Electrabel internal governance regarding Nuclear Safety and describes the Nuclear Safety Management System of the Nuclear Production of ENGIE Electrabel (NGMS). Through the management system, ENGIE Electrabel guarantees and continuously improves its nuclear safety performance based on standards and expectations, evolving with changing regulatory requirements and performance enhancing decisions.

Internal governance means « the needed organizational structures, policies, processes and

programs to establish high standards for executing the nuclear activities of ENGIE Electrabel, including the operation, maintenance and organizational support of the nuclear power plants. »

The NGMS is structured by grouping these activities & processes in a number of Functional Areas (FA), in which processes important to Nuclear Safety are clearly identified.

The standards & expectations for each of those FA's integrate all (regulatory) requirements related to nuclear safety and other specific (regulatory) requirements that could interact and could have a negative impact on nuclear safety during operation of the NPP, coming from industrial safety (OHSAS 18001), environment (ISO 14001) or any other governance applying to the FA.

The NGMS reference book is build up in compliance with regulatory requirements and includes:

- the company's policy statements on Nuclear Safety, H&S, Security and Environment
- the organizational structure of the nuclear activities
- a description of the management system NGMS and its Functional Areas (FA)
- a description of the method used to measure, assess and improve performance in the different FAs (including NGMS as a management system)
- functional responsibilities and responsibilities of Senior and Line Management
- a description how all related documentation is structured and managed
- an identification of the interactions with requirements other than Nuclear Safety related that apply to the operator (e.g. OHSAS18001, ISO 14001,…).
- the standards & expectations per FA.

The standards and expectations per Functional Area, are described and kept up to date in the "Governance Nuclear Activities ENGIE Electrabel" document.

e) Competence development

A general training is given regarding the quality assurance objectives and the means for achieving these to all personnel who perform safety-related activities in the various services. This training is maintained and updated when necessary.

f) Evaluation

Quality assurance is integrated directly in the different processes and procedures, important for the nuclear safety. Basics elements are the necessity to perform self-checks and peer-checks during the execution of the tasks, and to execute tests, inspections and verifications to provide evidence that a structure, system or component will perform satisfactorily in service.

(1) Nuclear safety oversight

Corporate oversight and monitoring are used to strengthen Nuclear Safety and improve performance. Plant safety and reliability are under constant scrutiny through techniques such as assessments, performance indicators, and periodic management meetings.

(2) Self-assessment (Management Reviews and Functional Area Health Reviews)

Management at all levels (Line Management, and Functional Area Management) carry out self-assessment with the objectives to:

- Evaluate the performance of work;
- Verify compliance with all aspects of the management system (legal and performing enhancing requirements).
- Prevent, identify and correct weaknesses that hinder the achievement of ENGIE Electrabel's objectives;
- Improve the management system;
- Enhance the Nuclear Safety culture and the effectiveness of processes and activities.

(3) Management System Review

A management system review is conducted at planned intervals at the Generation BE level to ensure the continuing suitability and effectiveness of the management system and its ability to enable the objectives set for ENGIE Electrabel to be accomplished and the Nuclear Safety policy to be met.

(4) Independent Nuclear Safety Oversight

The Health Physics Department ("Service de Contrôle Physique/Dienst voor Fysische Controle") is established with the responsibility for conducting these independent assessments. It has sufficient authority to discharge its responsibilities and has direct access to the Senior Management. Within this service, the roles and responsibilities of the Care departments and the ENGIE Electrabel Corporate Nuclear Safety Department are clearly defined. Independent oversight provides the ENGIE Electrabel Senior Management with an ongoing perspective of performance at the nuclear stations and in the corporate organization compared to the industry, with a principal focus on Nuclear Safety, plant reliability, and emergency response effectiveness.

The Independent Nuclear Safety Oversight embodies a comprehensive system of planned and periodic audits and assessments, to verify compliance with the different aspects of the management system.

(5) Nuclear Safety Committees

Within ENGIE Electrabel, Nuclear Safety Committees are defined at different level. Their objectives are to evaluate and continuously improve the Nuclear Safety performance and the Safety Culture of ENGIE Electrabel:

- The Plant Operating Review Committees (PORC, plant level),
- The Site Operating Review Committees (SORC, site level),
- The Independent Nuclear Safety Committee (INSC, fleet level)
- Nuclear Safety Committee (CSN, Board level)

II.I.2. Research Reactors

The development of and integrated management system (IMS) started from the existing quality assurance system for commercial isotope production. The IMS principles are defined and a number of important processes is described. In the future, the system will be further developed to include all processes concerning reactor operation and its utilisation (commercial isotope production and development of experiments). The IMS is applicable to all installations, and thus also includes the reactors.

II.I.3. Activities of the Regulatory Body

In 2010, FANC and Bel V asked the licensees of nuclear facilities (NPPs and RRs) to perform a gap analysis between their management system and the requirements of the safety standard GS-R-3. Since the SRNI-2011 came into force on the 1st March 2013, article 5 of SRNI-2011 imposes to the licensees of nuclear facilities to set up an integrated management system. This article is based on the WENRA reference level "issue C – Management System", which is itself derived from the IAEA Safety standard GS-R-3.

The results were received and analysed by FANC and Bel V. End 2012, FANC and Bel V sent the results of their analysis to the licensees and asked them to take the necessary corrective actions in order to be fully compliant with the GS-R-3 by the end of 2013.

In 2014 and 2015, an inspection campaign was conducted to verify the compliance of the management systems of the Belgian NPPs and other nuclear facilities (Belgoprocess, IRE and SCK•CEN).

The conclusion of the inspection campaign was that management systems were on the whole compliant with the regulatory requirements. Action plans were, however, set up in order to correct some issues related e.g. to documentation and performance indicators.

Bel V performs systematic inspections, with some dedicated to the assessment of the management system procedures related with the operation of the plant. The management system is also reviewed during examination of modifications to the installations, incident reports, etc.

II.J. Article 14. Assessment and Verification of Safety

> Each Contracting Party shall take the appropriate steps to ensure that:
>
> 1) comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;
> 2) verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

II.J.1. NPPs

a) Licensing Process

The process initially applied for licensing of the Belgian nuclear power plants was described in previous reports for the Convention. Since the process would no longer be the same today and since many organisations and committees that played a role in this process do no longer exist (being replaced by other organisations and committees), it was judged no longer appropriate to describe this historic information in this report. However, if needed, the reader can find the information in the 2007 report for the Convention (in particular in paragraphs II.B, II.D and II.J.1).

In section II.B.1 of this report, more information can be found concerning an important outcome of the original licensing of the NPPs, being the high level of protection against external accidents (airplane crash, explosion, large fire, toxic gases).

Furthermore, it is worthwhile to note that the Safety Analysis Report (SAR) of all plants are drawn up according to the standard format and content as applied in US, i.e. in accordance to Regulatory Guide 1.70 (revision 2 or 3). This was the case from the very beginning for the four more recent units (Doel 3 and 4, Tihange 2 and 3), while for the older units (Doel 1 & 2 and Tihange 1) the SAR was rewritten in this format afterwards, although minor deviations from the standard table of content of RG 1.70 may exist.

The table of content of the SAR was also extended:

- To include a new section (in Chapter 3) on the Probabilistic Safety Assessment performed for that plant (a consequence of the periodic safety reviews).
- To include a new section (in Chapter 3) on the Ageing Management Programme (a consequence of the WENRA Action plan, in particular WENRA Reference Level N.2.8).

Article 13 of the SRNI-2011 stipulates that the SAR shall be kept updated throughout the life of the installation so that the SAR exactly reflects its present state.

b) Periodic Safety Reviews

Article 14 of the SRNI-2011 requires a ten-yearly periodic safety review for each nuclear unit. The general objectives of these periodic safety reviews are as follows:

- to demonstrate that the unit has at least the same level of safety as it had when the licence was granted to operate it at full power, or since its latest periodic safety review;
- to inspect the condition of the unit, devoting more particular attention to ageing and wear and to other factors which may affect its safe operation during the next ten years;
- to justify the unit's current level of safety, taking into account the most recent safety regulations and practices and, if necessary, to propose appropriate improvements.

(1) Rules followed up to 2007

The initial licence of each nuclear unit made it mandatory to conduct periodic safety reviews. These safety reviews must "compare on the one hand the conditions of the installations and the implementation of the procedures that apply to them, and, on the other hand, the regulations, codes and practices in force in the United States and in the European Union.

The differences found must be identified, together with the necessity and possibility of remedial action and, as the case may be, the improvements that can be made and the time-schedule for their implementation".

The topics to be studied in these safety reviews are detailed in a report submitted by the licensee to the FANC; in this way the rules retained become mandatory.

The feedback of operational experience of nuclear power plants at the international level is also considered; in this respect the "Bulletins" and the "Generic Letters" of the USNCR, as well as information available from other regulatory bodies, are examined, if their follow-up has not yet been required in the frame of the permanent supervision during operation of the installation.

From this, one can conclude that all the new rules of the USNRC are not automatically applied in the Belgian plants, and that non-American rules, guides and practices can also be retained for implementation in Belgium.

The list of technical subjects examined during the successive periodic safety reviews is given in extenso in Appendix 5 to this Report.

(2) Additional rules followed from 2007 onwards

In 2007, the FANC has required that the future safety reviews of all nuclear units are carried out by using the IAEA Safety guide NS-G-2.10 superseded by SSG-25. In October 2018, the SRNI-2011 has been modified to require the use of 14 Safety Factors in line with the WENRA reference levels of issue P.

The objectives of the safety review are multiple. In the review, the operator should assess, for each safety factor, the state of the installation and the organisation in relation with international legislation, standards and good practices. Furthermore, strong points and weaknesses should be identified, as well as compensating measures in the case that some weak points possibly cannot be modified. Finally, the assessment should show to what extent the safety requirements of the Defence in Depth (DiD) concept are fulfilled, in particular for the basic safety functions of reactivity control, fuel cooling and the confinement of radioactive material.

At the end of the process, an action plan including the associated deadlines is established and has to be approved by the FANC. The action plan should then be implemented within a defined delay (3 to maximum 5 years).

c) During operation of the installations

According to the requirements of article 23 of GRR-2001, the proposals for modifications to the installation are examined and approved by the Health Physics Department of the operator. Each proposal is classified into one of the three following categories, according to the principles of the FANC guidance 006-029 for the treatment of modification projects in the context of article 12 of the GRR-2001 for Class I facilities:

- Major modifications that change the basic characteristics of the unit. These modifications are subject to the application for a licence under the provisions of Article 6 of the GRR-2001. A major modification requires a new licence application and follows a licensing scheme similar to that described in section II.C.7 : The safety assessment performed by Bel V is presented to the FANC. The results of this assessment are presented to the FANC's Scientific Council, who will produce its conclusions on the acceptability of the modification and will propose, if deemed necessary, additional operational conditions. A new Royal Decree of Authorisation is prepared by the FANC and finally signed by the Minister of Home Affairs and the King. After a fully favourable acceptance report of the modification, reviewed by Bel V, a new confirmation decree, allowing operation, is issued (see II.C.7).
- Less important modifications that have a potential impact on safety. In a first phase, the requesting department of the licensee, indicating the justification for the intervention, presents a proposal for modification. In a second phase, the proposal is examined on its technical merits, and later on also by a multidisciplinary team including a.o. the Health Physics Department. In the next phase, studies are completed and approval of both the Health Physics Department and of Bel V is sought before the implementation of the modifications. Further activities then imply the implementation and testing of the modifications. Commissioning of the completed modification is subject to a positive acceptance, issued after validation of the modification and re-

qualification of the portion of the installation that was modified, and updating the operational documents. The Health Physics Department formally approves of the modification when all the files, procedures and the Safety Analysis Report have been adequately updated. This decision of the Health Physics Department has then to be confirmed by Bel V before operation, on the basis of its independent safety assessment. Such modification can either be a hardware modification or an organisational modification.

- Modifications without impact on safety, that usually do not imply modification of the Safety Analysis Report and which comply with all the safety rules of the installation. These modifications have to be approved only by the Health Physics Department of the unit, without formal involvement of Bel V, except for the possible sections of the Safety Analysis Report to be updated.

The decision in which category a specific proposal for modification should be treated is done by Bel V, based on a motivated proposal made by the Health Physics Department of the licensee. This motivated proposal is based on the criteria defined by the FANC in the abovementioned guidance.

d) Certain studies relating to the modifications

Certain studies relating to modifications or initiated in the scope of the periodic safety reviews were so substantial that they had to be tackled as projects having their own specific structure:

- Severe accident analyses: ultimate strength of the containment in case of internal overpressure, installation of autocatalytic recombiners to prevent containment hydrogen build-up (installed in all the Belgian units), reactivity accidents during operation and during shut down states, installation of the filtered containment venting system.
- Power increase and burn-up cycle extension studies.
- Use of mixed core (presence in the core of fuel assemblies from different suppliers) requiring detailed studies regarding mechanical, neutronic and thermal-hydraulic compatibility.
- Replacement of the steam generators, whether or not linked to a power increase.
- Replacement of technologically obsolescent systems (instrumentation and control systems) addressing software qualification issues.
- Set up of an integrated ageing management system, in order to assure that safety related structures, systems and components remain qualified within their defined service life.
- Replacement of reactor pressure vessel head.
- Evaluation of the safety cases related to the reactor vessel flaws
- Continuous development of probabilistic safety analyses (PSAs) of L1 and L2 for the Doel and Tihange nuclear power plants (NPPs) performed by Tractebel ENGIE, on behalf of the utility ENGIE Electrabel.
- Extension of the PSA-models to include internal fire and flooding hazards
- Operational use of the PSA-models as additional tool for safety decision making
- The BEST action plan with a dedicated structure for the filtered containment venting systems
- Preparation for decommissioning and dismantling of Doel 3 and Tihange 2

More details on the topics mentioned can be found in previous national reports.

e) Verification Programmes

The technical specifications (chapter 16 of the Safety Analysis Report) were examined at the time of the licensing process; their amendment during operation falls under the prescriptions for modifications that are subject only to approval by the operator's Health Physics Department and by Bel V. These technical specifications are reviewed in the frame of the period safety reviews. They have been completely rewritten at least once during the life of each nuclear power plant.

These specifications indicate for each status of the unit the operational limits and conditions, specifying also the actions to be taken if limits are exceeded. They also list the inspections and tests to be performed and their periodicity.

Specific programmes are established, in particular for:

- examinations and tests required by the ASME Code.

- inspection and repair of the steam generator tubes.
- fire protection.
- tests of ventilation filters.
- inspection of the primary pump fly-wheels.
- examination of irradiation samples of the pressure vessel.

Each safety-related equipment has a qualification file that contains all the qualification test requirements and results. In this file are also recorded the results of ageing tests or experience feedback of similar equipment, so defining the qualified life of the equipment. The qualified life determines the frequency of replacement of that equipment, which can be re-assessed in function of the real operational conditions and location of that equipment.

The reactor coolant pressure boundary is treated in a specific way. It was originally designed to ensure a minimum useful life taking into account a limited number of transients during normal, incidental and accidental operation. As for the reactor vessel, it is monitored according to the transition temperature evolution (NDT) based on an irradiated samples withdrawal programme. The occurrence rate of the design transients is strictly recorded under the close supervision of Bel V.

An In-Service Inspection programme is permanently implemented by personnel specifically qualified for these inspections, which are carried out during power operation of the unit or in shut down states.

All these tests and inspections are performed under fully detailed documented procedures.

II.J.2. Research Reactors

a) Main Results of Continuous and Periodic Safety Monitoring

The continuous safety monitoring can lead to modifications. These are treated by the same process as above described for the NPPs.

Experimental devices are not necessarily considered as a modification of the reactor. A dedicated stepwise approval system was developed and is currently under review for further improvement. The experiment is at first discussed in an internal advisory committee. Based on the advice, the experiment has to be approved by the Health Physics Department and Bel V has to confirm this decision.

The installations of the SCK•CEN are also subject to periodic safety reviews. Previously the reactors BR1 and BR2 had to undergo a 5 yearly safety review according to the licence for operation of the SCK•CEN installations. In 2003 the periodicity of the safety reviews was changed by Royal Decree to 10 years for all the SCK•CEN installations, as is the practice for nuclear power plants. The current (2016) periodic safety review is based on IAEA SSG-25. A significant part of the actions defined in the PSR 2016 were completed in recent years and most of the remaining action will be finalized in 2019.

b) BR1

The current (2016) safety review of BR1 includes the following important topics:

- Study of reduction and optimization of storage of combustible radioactive waste and feasibility study for storage of spent fuel from BR1.
- SSCs: Identification, classification, ageing and study of replacement by state of the art components.
- Re-evaluation of standard accident and DBA's: Complete loss of cooling and Reactivity Insertion at start-up.
- Organisation and procedures: Evaluation of tasks and functions of the operation's team for BR1 (and VENUS) and GAP-analysis with existing procedures and Integrated Management System.
- Assessment of the emergency plan for BR1.

c) BR2

In 2016 the beryllium matrix of BR2 was replaced. According to the licence the matrix has to be inspected on regular intervals to follow cracking. Due to neutron irradiation, gases (helium and tritium) are formed in the beryllium. This causes swelling and the initial space between the beryllium blocks will be consumed and blocks will make contact with each other. The cracks are caused by deformation and mechanical stresses. The licence specifies that the beryllium matrix must be replaced if the inspection indicates that there is a risk of losing material. At the latest, the replacement must be done if the fluence reaches 6.4×10^{22} fast neutrons per cm^2 for the most irradiated channel. The previous matrix had not yet reached its end of life. However due to the formation of He-3 the beryllium gets poisoned.

The reactivity effect has adverse effects on the flexibility for operation (such as the maximum duration of a shutdown). For this reason, the management of SCK•CEN decided to replace the matrix earlier. The replacement was finished mid-2016 and the reactor was restarted July 2016.

In case of replacement of the matrix, an inspection of the vessel, made of aluminium 5052-O, is also required by the licence. In fact, this is the only occasion when the vessel wall is accessible from inside. An inspection of the vessel was carried out in September 2015 using the same methodology and criteria as in 1996. Since the knowledge of irradiated aluminium is limited, the vessel assessment project is completed with the irradiation of samples taken from the shroud around the vessel. The samples are used to predict the mechanical properties (especially the fracture toughness) of the irradiation aluminium as a function of the neutron dose. The program shows that the mechanical properties of the vessel material could be sufficient to allow operation beyond 2026. Over the next years, the follow up program about the properties of irradiated aluminium 5052-O will be continued.

During the last years, a number of safety upgrades have been made. The most important is the replacement of the diesel generators. The new system is based on fly wheel generators for feeding the vital electrical grid. In normal operation the fly wheels are driven by the external grid. In case of loss of the grid, the fly wheels are powered by diesel generators. This system guarantees emergency power without any interruption in case of loss of the external grid. The electric grid has also been split into two separate trains.

A non-destructive inspection of the primary piping has been performed according to the principles of the ASME BPV Code, Section XI: In Service Inspection for Nuclear Power Plant Components. Since this is the first systematic inspection executed during the operation of the of the reactor, it is considered as the basis for following up during the further operation of the reactor. These in service inspection will also be done according the ASM XI inspection scheme.

II.K. Article 15. Radiation Protection

Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

II.K.1. Design

Chapter III "General Protection" of the GRR-1963 introduced from the very beginning in Belgian law the radiological protection principles.

Belgian nuclear power plants design was done according to that legislation and, furthermore, consistent with the US regulations and in particular 10 CFR50 Appendix I and the related Regulatory Guide 1.21. In fact, as demonstrated in the Safety Analysis Reports of Belgium's units, the objectives of the US regulations were amply met, considering that the doses to the population computed according to the US rules are smaller by a factor of at least 3 than the criteria prescribed by these rules.

The releases limits, in annual average or in instantaneous value, were presented in the Report to the European Commission (application of article 37 of the Euratom Treaty) and are discussed in the Safety Analysis Report (chapter 11). At the Belgian units the liquid effluents are released via one single pipe that groups the primary and secondary effluents and which is redundantly and automatically isolated in case an instantaneous limit is exceeded.

II.K.2.NPP Operation

a) ALARA Policy

Operational radiological protection programmes are inspired from chapter III of the GRR-2001 and from IAEA NS-G-2.7 (2002). Those programmes cover among others:

- Protective clothing and equipment,
- Training,
- Monitoring of individuals and workplace,
- Emergency plan,
- Health surveillance,
- Optimisation of protection,
- Etc.

The evolution has been taken into account, e.g. the introduction of the recommendations of the ICRP documents and the implementation of the Directive 96/29/EURATOM into the Belgian regulations.

To anticipate the implementation of these regulations ENGIE Electrabel has, on a voluntary basis, limited the individual worker dose at about the half of the dose limit which is 20 mSv for 12 consecutive months, in accordance with the GRR-2001.

Protection of the public is assured through limitation of the radioactive liquid and atmospheric releases. Those limits are presented in the Report for the European Commission (application of article 37 of the Euratom Treaty) and are discussed in the Safety Analysis Report (chapter 11), ensuring to limit the maximum dose to the individuals of the critical group well below 1 mSv per year.

b) Implementation of radiation protection programmes

Dosimetric results

Various measures have been taken over the years to reduce the annual collective dose: the average value for the 7 Belgian units has been reduced by a factor of more than 4 during the 1990-2015 period.

Figure 11 represents the evolution of the outage collective doses of the Doel and Tihange sites since 1974.

The rise between 1974 and 1985 corresponds to the progressive start-up of the new units. The Tihange peak in 1986 is due to the extensive works linked to the first periodic safety review.

As the Tihange units operate along cycles up to 18 months, the number of refuelling outages varies from one year to the other, which introduces variations on the annual collective doses. Another factor of variation is the cumulated dose due to the replacement of steam generators at both Doel and Tihange. The introduction of an outage cycle of 18 months for Doel 4 in 2009 did not induce any significant variation in annual doses for the Doel NPP.

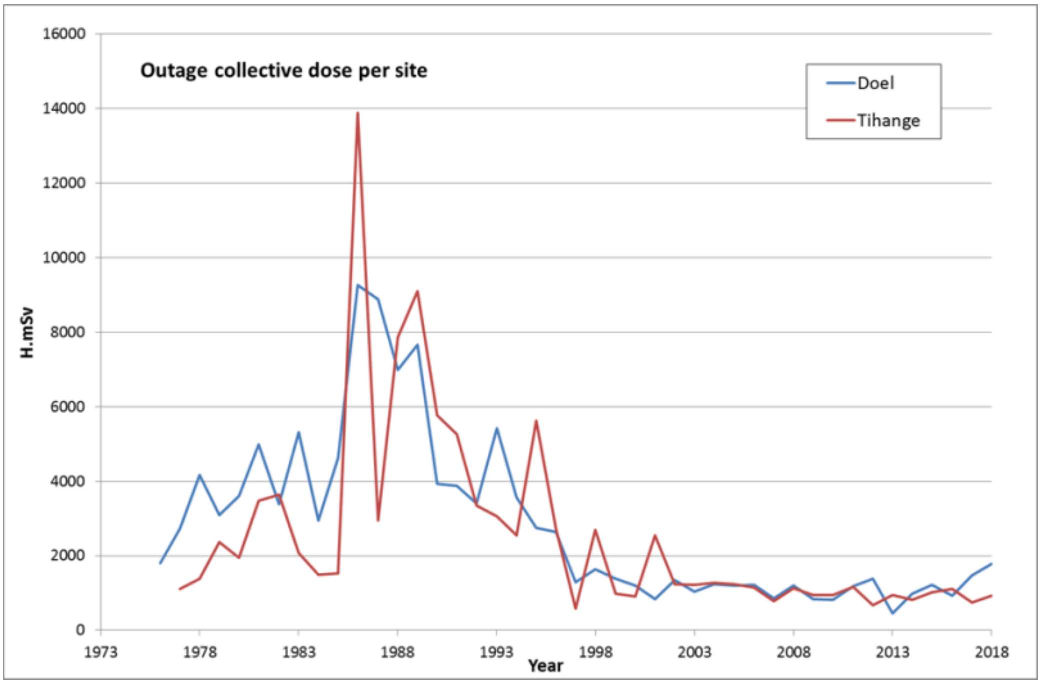

Figure 11 : Collective dose per outage

From 2017 onward, the radiological intensity of works during the outages at Tihange 1 and Doel 1&2 increased due to the projects executed in the framework of Long Term Operation (LTO). Examples include repairs on the reactor pressure vessel lid of Doel 1.

Actual individual exposure of workers amounts to an average of ~ 0.5 mSv per year. The dose constraint of 10 mSv per year, applied according to internal ENGIE Electrabel policies, had to be exceeded in 2018 for the first time since 2006, due to the specialized work that needed to be carry out in high radiation fields next to the reactor pressure vessel, for the repairs on the Upper Plenum Injection pipe at Doel 1 and 2 (see section I.C.4.c). It should be noted that these works were thoroughly prepared beforehand, amongst others by placing lead shielding and training on a mock-up. No worker exceeded the legal limit of 20 mSv per year.

Good radiation protection performances are achieved through the optimisation of several parameters, whose main ones are briefly discussed below:

- The source term (dose rate and contamination),
- The monitoring of working places and individuals,
- The protective means (shielding and protective clothes),
- The time of exposure,
- The distance from the source term,
- The radiation protection culture.

<u>Reduction of the source term</u>

The primary system chemical conditioning procedure applied in preparation of the core refuelling outages proved to be very effective to reduce the dose rates induced by the contaminated systems: a continuous decrease in mean dose rates has been recorded for the primary loops. This procedure was developed thanks to operational experience feedback from pressurised water reactors.

During the period 2007 – 2009, ENGIE Electrabel investigated the possibility to decrease the source term of plants characterized by higher figures than the average. Therefore, Doel NPP planned to initiate Zinc injection into the primary fluid of Doel 3 from 2010. Zinc injection is fully implemented since April 2011 and injection is still going on as of 2019. Over the years, the ^{60}Co surface activity decreased, and there has been a higher decrease of the ex-core dose rates during the last cycles, which can be linked to the zinc injection.

In the period 2000 - 2007, statistics of fuel failures seemed to indicate a slight increasing trend. Therefore, ENGIE Electrabel put additional effort aimed at preserving the integrity of the 1st and 2nd barrier:

- Pay a special attention to the fuel assemblies' quality,
- Develop an intensive Foreign Material Exclusion (FME) programme,
- And develop an intensive programme of leakages tracking.

This effort proved to be efficient from 2009 onwards. During the past years, no new leaking fuel rods were detected.

Finally, since 2007, special effort is put on the improvement of the radiological cleanliness of the workplaces, connected to the associated monitoring (see below). The whole ENGIE Electrabel fleet can now display the following contamination performances:

- More than 97% of the Radiation Controlled Area (RCA) rooms are radiologically clean (i.e. surface contamination < 0,4 Bq/cm2);
- Residual individual contamination rate at the exit of RCA ranges between 0,5 and 1,5%, with an objective of being below 1%.

Monitoring of the working places and individuals

Systematic measurement is done daily of the surface contamination of the floors in representative locations during the outage. Immediate decontamination action is taken should a problem be detected. Effectiveness of the housekeeping activities inside the controlled area is pursued. Additional portable means for measuring the volumic activity (aerosols, iodine, and gases) are placed at the pool floor of the reactor building and at the access locks to the steam generators.

Since 2007, ENGIE Electrabel improves the monitoring of the radiological cleanliness, covering the monitoring of the radiological cleanliness of the (un)clean working areas, monitoring of the contaminated individuals at the exit of radiation controlled area (RCA) and the tracking and elimination of the cause of contamination.

Signalling of the hot points and the ambient dose rates informs the workers about the ambient radiological conditions in which they will carry out the work: access is denied to certain locations, without specific permission of the Radiological Protection Department. Specific radiation signalling indicates very low dose-rate areas ("green" area) which the workers may use as an identified falling-back station.

Personal dosimetry of the workers is achieved through the simultaneous wearing of a passive and an active (electronic) dosimeters. The latter one is set up in order to alert the worker in case excessive dose and dose rate, depending on the type of work. Throughout the outage period, the actual-versus-estimated dosimetry trends are monitored daily, and any significant deviation is analysed and may result in corrective actions.

On 1st Jan 2012, the Tihange NPP replaced the passive film dosimeters (which are becoming obsolete) by the more precise, state-of-the-art Optically Stimulated Luminescent (OSL) dosimeters.

From 2015 to 2017, the Doel NPP replaced the electronic personal dosimeters (EPD's). From 2018 onwards, the progressive replacement of the passive film dosimeters with OSL dosimeters is also carried out. At the moment, the intervention and BEST dosimeters are already replaced by OSL dosimeters.

Protective means

Shielding is systematically installed at various locations during core refuelling outages: primary pump cell floor, between steam generator and primary pump, around pressure vessel-head on its stand, vessel-well decompression piping, corridor at the hot penetrations, places of passage and waiting (access locks to the steam generators...), hand-holes of the steam generators...

Specific shields are also installed when deemed necessary with regard to the size of the work: pressuriser dome, valves, detected hot points...

Protective clothing is foreseen for both regular entrance in radiologically controlled areas and for work requiring breath protection clothing.

Reducing time of exposure

Reducing the time of exposure is achieved through appropriate:

- pre-job briefing,
- training on make-up facilities,
- experience feedback,
- etc.

For interventions in areas with high radiation fields, for example the inspections and repairs of the Upper Plenum Injection pipe next to the reactor pressure vessel at Doel 1 and 2 in 2018, operators first have to train beforehand on a model before work authorisation. During the last years, additional effort was also set on the avoidance of "search dose", starting from the statement that a significant part of the workers exposure came from the initial step of just finding the equipment(s) on which one has to intervene.

Distance from the source

Keeping distance from the radiation source considered in the work preparation and supported by the monitoring system and the related databases (e.g. see above about the "green area").

Radiation protection culture

Internal and external workers are all committed to follow a base training "nuclear safety culture" encompassing radiation protection, prior to gaining access to the controlled zone of the Nuclear Power Plant. This base training includes sessions in a simulator area. A yearly refresher training is mandatory as well. Both the base and refresher training are used as opportunity to highlight the various parameters that intervene in order to reach good radiation protection results.

Late 2015, both sites of Doel and Tihange launched the project to enhance the representativeness of the simulation school, using pseudo radioactive contaminants and simulating the radiation fields, coupled to active electronic personal dosimeters.

c) Radioactive Releases

Discharges are defined as authorised and controlled releases into the environment, within limits set by the licence and regulations. In addition, there are operational release limits (limiting the release on time based assumptions), related with a scheme to notify the operators, the Health Physics Department, Bel V and the FANC.

The radiological impact of the authorized release limits to the most exposed individual of the public are given in the Table 7:

	Gaseous releases	Liquid releases	**Total[6] maximum**
Tihange Site (3 units)	190µSv	80µSv	**210µSv**
Doel Site (4 units)	180µSv	230µSv	**370µSv**

Table 7 : Impact of Release Limits

From 1st January 2011, the radioactive releases have to be reported to the Belgian Safety Authorities following a new method, inspired from the 2004/2/Euratom Recommendation and ISO 11929 standard. The impact of this new approach was significant, as the methodology implies a conservative declaration of isotopes below the detection level of the measurement devices, which automatically increases the release figures:

- **Iodine releases**: more than 10 % increase,
- **Aerosols releases**: more than 100 MBq/year in total for both sites, due to the fact that about 20 isotopes are below detection level and must be declared as a fixed amount.
- **Liquid releases**: about 2 times the previously declared values for both sites, due to the reason mentioned for aerosols.
- **Tritium releases**: no significant change.

The releases that take place effectively are only a few per cent of the limit values, except for tritium where the limit values had been chosen based on the operational experience of similar plants.

[6] the total maximum is not the sum of the dose due to the gaseous release and the dose due to the liquid release because the most exposed individual by each type of release is in not in the same age category

	Tihange Nuclear Power Plant				
	Gaseous releases			Liquid releases	
	Noble Gas GBq	Iodine MBq	Aerosols MBq	βγ GBq	Tritium GBq
Annual limit	2 220 000	14 800	111 000	888	148 000
2008-2010 average	15 433	23	3,4	13	47 367
2011-2015 average	6054	14	250,2	10,7	40973
2016 values	4910	8	320	15	40640
2017 values	5140	8	269	16	28350
2016-2017 % of the limit	**0,23**	**0,05**	**0,27**	**1,74**	**23,31**

	Doel Nuclear Power Plant				
	Gaseous releases			Liquid releases	
	Noble Gas GBq	Iodine MBq	Aerosols MBq	βγ GBq	Tritium GBq
Annual limit	2 960 000	14 800	148 000	1 480	103 600
2008-2010 average	25	62	6,1	3,5	48 870
2011-2015 average	37594	53	96,4	4,9	39293
2016 values	48233	27	84,1	3,8	41814
2017 values	27402	6,3	59,2	4,3	37931
2016-2017 % of the limit	**1,28**	**0,11**	**0,048**	**0,27**	**38,49**

Table 8 : Release to the environment of the NPP-sites

Radiation monitoring of the environment and assessment of public health impact is assured by a programme set up and managed by the FANC, as stipulated in Article 71 of the GRR-2001. However, a side surveillance program performed by the ENGIE Electrabel, in the vicinity of the plants, has been developed, as follows:

Specific sample	Location and frequency	Measurement specifications
Terrestrial bio-indicator (lichen or mosses)	Annually on 2 locations in most prevalent wind direction and on 1 reference location	γ spectroscopy ($^{134,137}Cs$, ^{131}I, ^{60}Co), ^{3}H, ^{14}C
Aquatic bio-indicator (algae, seaweed, mussels)[1]	Annually on 2 locations downstream and on 1 reference location upstream	γ spectroscopy ($^{134,137}Cs$, ^{131}I, ^{60}Co, ^{95}Nb, ^{110m}Ag), ^{3}H, ^{14}C
Soil (pasture soil)	Annually on 2 locations in prevalent wind direction and on 1 reference location	γ spectroscopy ($^{134,137}Cs$, ^{131}I, ^{60}Co), ^{3}H, ^{14}C
Grass (pasture)	Annually on 2 locations in prevalent wind direction and on 1 reference location (see soil sampling)	γ spectroscopy ($^{134,137}Cs$, ^{131}I, ^{60}Co), ^{3}H, ^{14}C
Sediment	Annually in river Meuse or Scheldt, two sediment samples downstream in addition to the sediment sampling in the monitoring campaign of FANC/AFCN within 10 km from NPP and at 1 reference location upstream.	γ spectroscopy ($^{134,137}Cs$, ^{131}I, ^{60}Co, ^{95}Nb, ^{110m}Ag)

Table 9 : Surveillance programme performed by ENGIE Electrabel

II.K.3.Research reactors

The management of the SCK•CEN introduced 10 mSv per year as a dose constraint for the personnel. Beside this constraint the SCK•CEN has an active ALARA policy. Each task with a potential exposure is analysed before starting and dose optimisation is performed. Afterwards, the predicted doses are compared with the real measured dose, in order to learn from the experience such that predictions for future tasks can be improved. Due to this ALARA policy, the radiation dose for the personnel has been reduced. During the last years, the total collective dose per year is about 130 man.mSv, for about 700 persons. More important, the maximum individual dose during the last years has always been lower than 10 mSv per year. A collective dose of about 70 man.mSv can be attributed to the operation of BR2. This figure remains fairly constant during the last years. The higher value for 2015 (91 man.mSv) is caused by the unloading of the matrix and a large number of inspections during the shutdown. The collective dose for BR1 operation is about 3 man.mSv per year and remains stable during the last years. The main contribution to the dose is the handling of experiments, such as neutron activation analysis and reactor dosimetry.

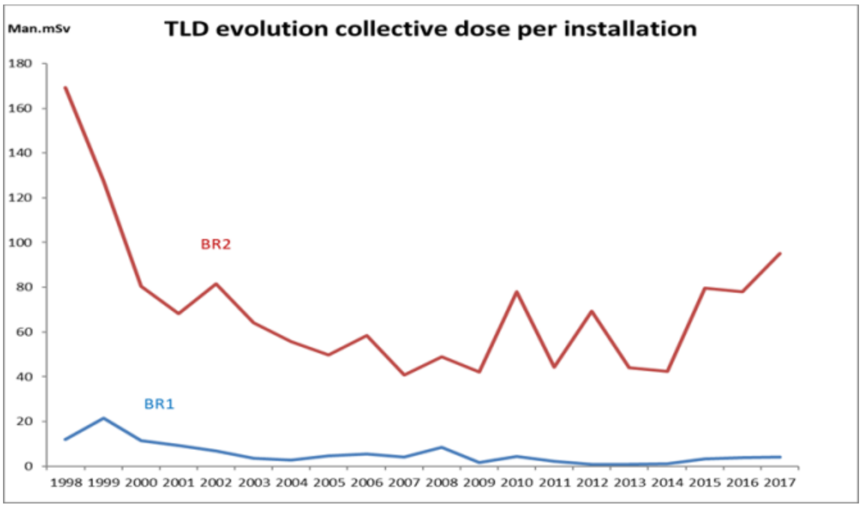

Figure 12 : Total Dose evolution per installation

Gaseous releases

The limits for the releases are defined such that the most exposed person in the environment could receive an effective dose of 100 µSv per year due to the operation of the SCK•CEN installations. 10 µSv per year is assigned to the operation of BR1 and 20 µSv per year to the operation of BR2.

The following gaseous releases are considered:

For BR1: βγ activity of aerosols and I-131. Since BR1 is an air cooled reactor, it releases also Ar-41. The released activity is directly proportional to the reactor power and the releases of Ar-41 are calculated, not measured.

For BR2: βγ activity of aerosols, α activity of aerosols, I-131, tritium and noble gases.

The releases of the last years are indicated in the following figures. It is to be noted that BR2 stopped in February 2015 for replacement of the beryllium core and was restarted June 2017. The following comments could be made on the releases:

The increased release from BR1 of Iodine can be attributed to a higher number of operational days per year.

The release level of noble gases in BR2 is normally below detection level. However, there have been a number of air cooled experiments. These caused the release of argon-41 as an activation product.

The main source for release of gaseous tritium is an old experimental device where helium-3 was used as a variable neutron screen. Irradiation with neutrons of helium-3 results in tritium. The installation is still present at the moment, but screens are no longer used with helium-3. However, they still release some tritium.

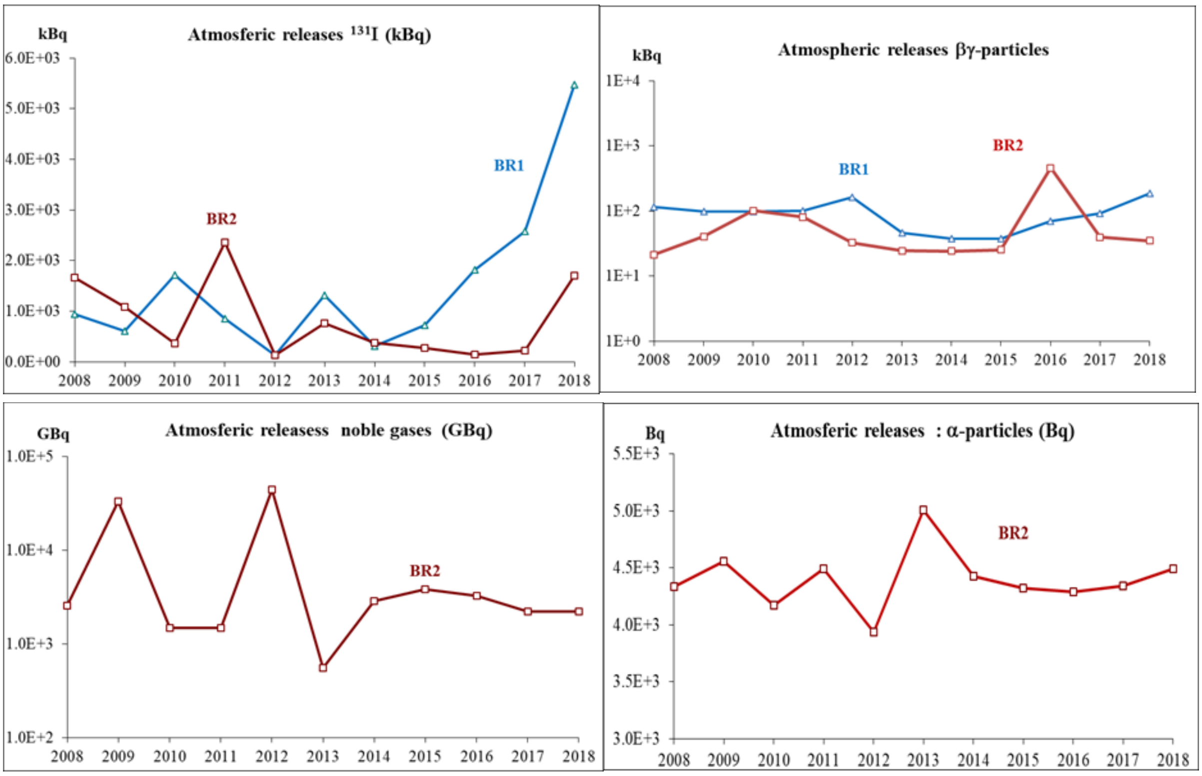

Figure 13 : Atmospheric Releases for SCK•CEN

Liquid releases

The SCK•CEN has no direct releases of liquid radioactive waste. All potentially contaminated water is sent to the waste treatment installation of Belgoprocess, where the water is treated before release to environment.

Environmental control

In addition to the direct stack measurements, 6 air measurement points are available around the site of the SCK•CEN. The a- and β- activity of air samples is continuously measured. Air samples of one of these measurement points is analysed monthly by spectrometry, in order to have an absolute measurement of the air contamination.

Possible water contamination is checked in four different situations: surface water (running water and water from lakes), ground water and drinking water. In routine, the total beta- and gamma- activity and the concentration of tritiated water is measured. On request other measurements are possible.

Regular samples of milk and grass of a neighbouring farm are taken and measured by spectrometry for potential radioactive contamination

The above mentioned programme is managed by SCK•CEN and complemented with an automatic monitoring network for airborne radioactivity and a surveillance programme of the territory and the food-chain under initiative of the FANC.

II.K.4. Regulatory activities

a) Radiological surveillance of the Belgian territory

The TELERAD network is the automatic measurement and alarm network for radioactivity on Belgian territory. It consists of 250 measuring stations that continuously measure the radioactivity in the air and the water of the rivers and is discussed in more detail in section II.L.2.b).

In addition to this network there is a radiological monitoring program of the territory, which is currently based on more than 4660 annual samples, which are the subject of nearly 28 000 analyses of alpha, beta and gamma radiation.

The samples are taken by specialized teams on behalf of the FANC. They are then analysed in laboratories to accurately determine the nature and level of radioactivity that they contain. The FANC then centralises, analyses and interprets the results obtained.

b) International Exchanges

The regulatory body and the Belgian operators participate actively since 1991 in the ISOE (Information System on Occupational Exposure) programme of OECD's Nuclear Energy Agency.

The Belgian NPPs operator is also participant in the working groups of the VGB (Germany).

II.L. Article 16. Emergency Preparedness

1) Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.
2) Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of a nuclear installation are provided with appropriate information for emergency planning and response.
3) Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

II.L.1. Legal and Regulatory Framework

- The GRR-2001 in its Article 72 requires an emergency plan for the regulated installations potentially presenting a serious radiological risk.
- Article 16 of the Royal Decree of 30 November 2011 requires each licensee of a Class I facility to set up an internal Emergency plan.
- The Royal Decree of 1st March 2018 (which replaced the Royal Decree of 17 October 2003) defines a nuclear and radiological emergency plan for the Belgian territory.

II.L.2. Implementation of Emergency Organisation in the Event of an Emergency

a) Classification of Emergency

The Royal Decree of 1 March 2018 defines three levels for the notification of emergencies according to the classification systems of GSR-7, which are in ascending order of seriousness Facility Emergency, Site Area Emergency and General Emergency, which the operator must use when warning the National Crisis Centre which assembles under the authority of the Minister of Home Affairs. In addition, a fourth notification level (General Emergency in 'reflex' mode) has been considered to cope with events with fast kinetics. In case an emergency situation is quickly developing (fast kinetics) and might lead within 4 hours to a radiation exposure of the population above an intervention reference level, immediate protective actions for the off-site population – without any assessment – are taken by the local authorities (Governor of the Province), waiting for the full activation of the emergency cells. The "automatic" protective actions taken under this "reflex"-phase are essentially limited to **warning**, **sheltering** and **keep listening** within a predefined **reflex zone**. Once the crisis cells and committees are installed and operational, the Emergency Director of the authorities will decide to cancel the reflex phase and to replace it by the proper emergency level. In such case the governor of the province hosting the nuclear site is immediately notified in parallel to the warning message to the National Crisis Centre. For each of these 4 notification levels (Facility Emergency, Site Area Emergency, General Emergency and General Emergency in 'reflex' mode) the notification criteria are defined in the Royal Decree of 1 March 2018. In addition, for each nuclear installation concerned, a set of particular types of events is established for each of the notification levels. In the specific case of the General Emergency in 'reflex' mode notification level, the activation criteria are based on predefined scenarios.

For example, the criterion associated with the Facility Emergency level is defined as follows: "Event which implies a potential or real degradation of the safety level of the installation and which could further degenerate with important radiological consequences for the environment of the site. Radioactive releases, if any, are still limited and there is no immediate off-site threat (no action requested to protect the population, the food chain or drinking water). Actions to protect workers and visitors on site might be necessary."

Each of these 4 notification levels (Facility Emergency, Site Area Emergency, General Emergency and General Emergency in 'reflex' mode) activates the federal emergency plan. In addition to these four levels, a "Alert" level is defined for notifying the Authorities in case of a serious enough operational anomaly that request an evaluation by the regulatory body (concertation between FANC and Bel V) to decide whether or not it is worth activating the emergency plan. Other minor operational anomalies and situations that could raise public interest (such as any intervention of emergency services on site) must be communicated to the authorities, immediately or on the first next working day according to criteria for "Declaration" stated by the regulatory body.

All emergencies (Facility Emergency, Site Area Emergency, General Emergency and General Emergency in 'reflex' mode) have to be notified to the National Crisis Centre. This permanently manned centre alerts and mobilizes the cells involved in the crisis management at the federal level (Management Cell Federal Coordination Committee, Evaluation Cell, Measurement Cell, Information Cell) and houses these cells during the crisis situation as well.

In the case of General Emergency in 'reflex' mode, the Governor of the province hosting the nuclear site immediately takes the 'reflex' protective actions (warning, sheltering and keep listening) in a pre-defined 'reflex' zone around the affected site. As soon as all the National Crisis Centre's cells are in place and operational, the General Emergency in 'reflex' mode level will be later converted to an appropriate emergency level (Facility Emergency, Site Area Emergency or General Emergency) by the emergency director of the authority according to the evaluation of the situation and possible consequences. At that time the responsibility of the conduct of the operations returns to the Federal Minister of Home Affairs (or his representative).

b) National Master Plan for Organisation in the Event of Emergencies

The National Crisis Centre (CGCCR in figure 13) is composed of the "Federal Co-ordination Committee" chaired by the Emergency Director of the Authorities, of the evaluation cell, of the measurement cell, and of the information cell, as indicated in the figure below.

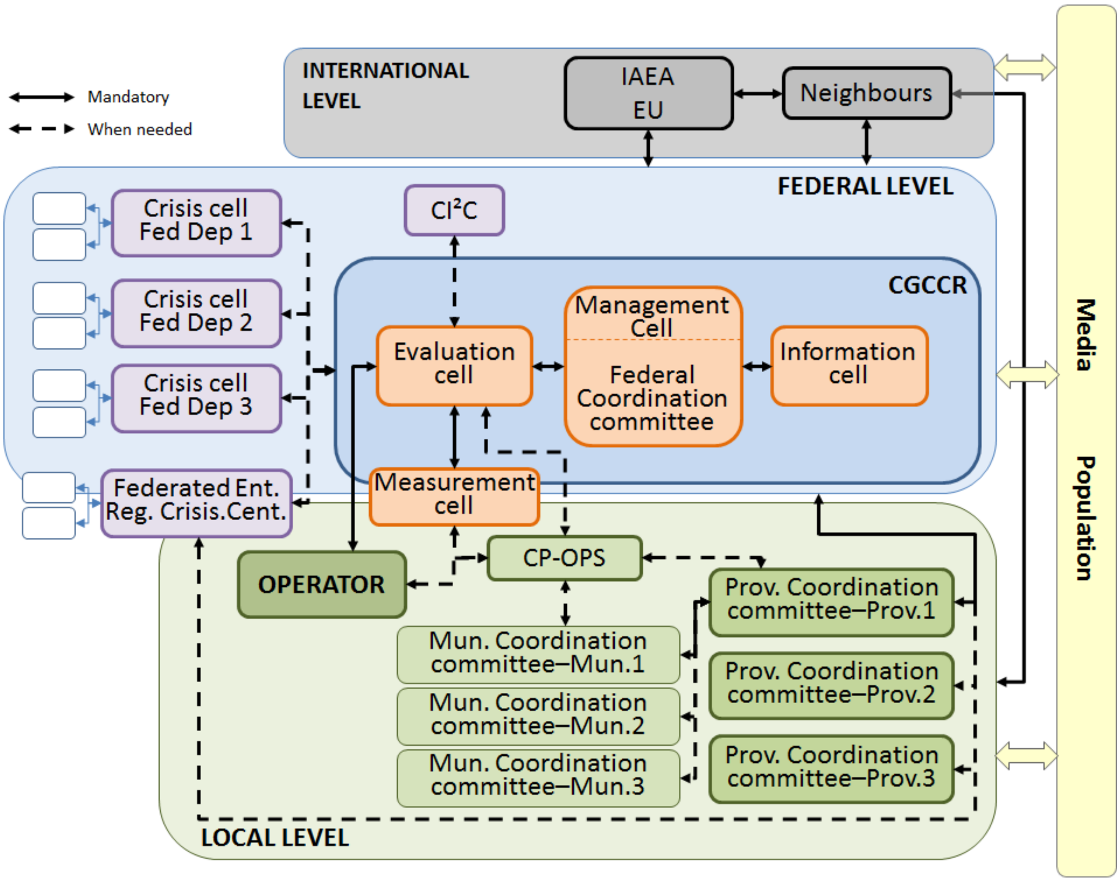

Figure 14 : EP&R organisation for Belgium

In case of an accident abroad, the National Crisis Centre, as National Warning Point (NWP), is informed by the Ministry of Foreign Affairs, the IAEA (through quick information exchange system USIE), the European Commission (through the European Commission Urgent Radiological Information Exchange system) or other reliable sources. The "Emergency Director" of the Authorities as National Competent Authority for accidents Abroad (NCA-A) could also be informed by the IAEA and/or the EC. This information channel provides possible redundancy. In case of an accident in a Belgian installation, the operator’s “Emergency Director” informs the National Crisis Centre and supplies all the information that becomes known to him as the accident evolves.

The data received through Belgium’s TELERAD network for automatic radiological monitoring can also be accessed by the National Crisis Centre and internationally through EURDEP and IRMIS. TELERAD is a network with the principal aim to measure routinely the radioactivity and to make measurements in case of an accident occurring in a Belgian nuclear site or abroad. The monitoring of the territory consists in a measurement network having a 20 km mesh (GM detectors), measurement stations in the vicinity of the Belgian nuclear installations and along the Belgian border in the vicinity of nuclear power plants in neighbouring countries. Around the Belgian nuclear sites, the network is arranged in two rings: the first ring (NaI scintillators) is on the site border and measures ambient radioactivity around the site, the second ring (GM detectors) covers the near residential zone, between 3 and 8 km from the site, depending on the direction. The monitoring network has 226 stations for the measurement of the ambient dose rate in air, 7 stations for the measurement of iodine and β/γ in aerosols and 11 stations for the measurement of radiation in river water; 13 stations are complemented with a meteorological mast.

Next to the fixed measuring station network, 24 mobile measuring devices (GM detectors) are available to be positioned where needed e.g. to fill up gaps between fixed stations.

Figure 15 depicts the TELERAD network:

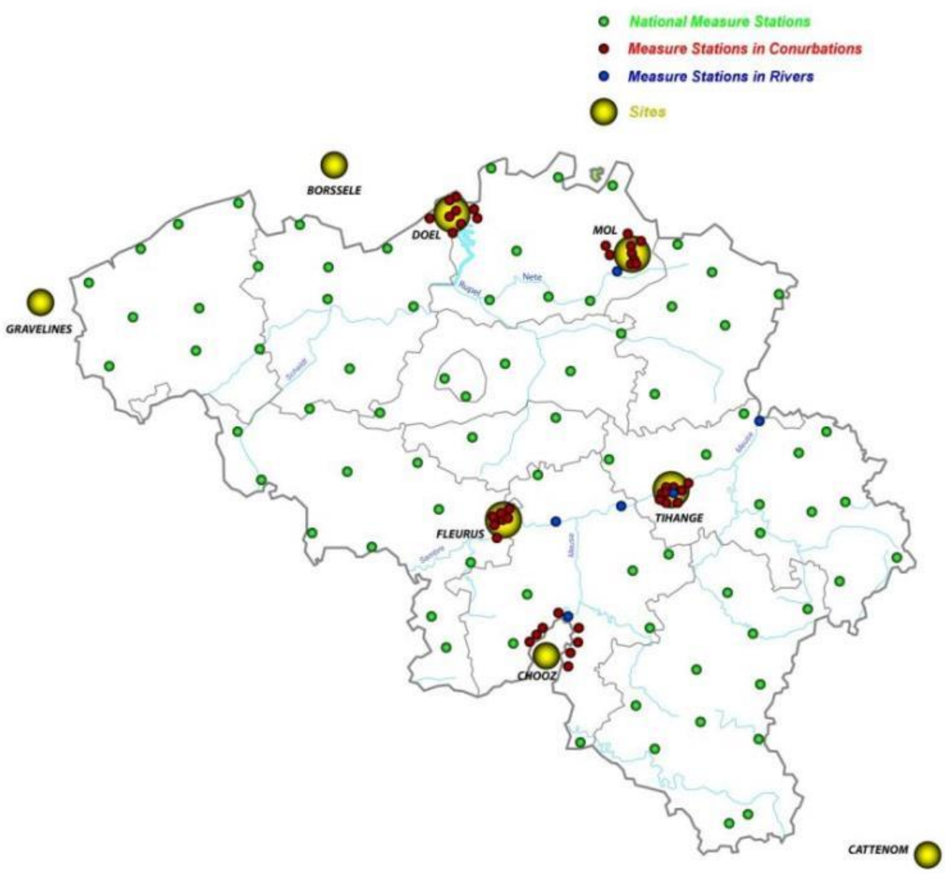

Figure 15 : TELERAD Network: location of the measuring stations

The Federal Management Cell, together with the Federal Coordination Committee, is the official leader of the conduct of the operation in case of an emergency. It defines the general strategy to deal with the emergency, takes the basic decisions (need and extent of direct protective actions for the population and/or for the food chain or the drinking water supply) and assumes the political responsibilities. The Management cell leans notably on the advices of the Evaluation cell on radiological aspects and on the relevant crisis cells of ministerial departments for the socio-economic aspects. The decisions taken are then transmitted for practical implementation and execution to the Provincial Crisis Centre, managing all the multidisciplinary intervention teams (fire brigades, civil protection, police, medical emergency services...).

The evaluation cell is composed of representatives of the relevant departments (in particular the FANC which chairs the cell), the Federal Public Service of Public Health, the Royal Institute of Meteorology, and of experts of the SCK•CEN, the "Institut des Radioéléments", and of Bel V that supervises these installations, as well as of a representative of the operator of the facility. This cell gathers and evaluates all information received from the affected installation, the off-site radiological measurement results received from the Measurement Cell and information from institutions represented in the evaluation cell. It evaluates the installation status and its estimated time evolution in order to assess the real or potential impact of the event. Then, it advises the decision cell on protective actions for the protection of the population and the environment. This advice is elaborated on the basis of intervention criteria provided in the NEP. The evaluation cell is also responsible for the preparation of the relevant information to be communicated to neighbouring countries and to the international organisations (European Commission, IAEA) in accordance with the Convention on Early Notification of a nuclear Accident and the "Ecurie" convention.

The measurement cell co-ordinates all the activities related to the gathering of field radiological information (external radiation in the air and from the deposits, samples measurements ...) transmitted either by the automatic radiological measurements network, TELERAD, or by the field teams. The measurement cell then transmits the collected and validated information to the evaluation cell.

The information cell is in charge of communications with the media and the population as well as with the neighbouring countries and specific target groups.

The relevant crisis cells of ministerial departments advise the Federal Coordination Committee on the feasibility and economic and social consequences of their decisions; it informs the Federal Coordination Committee about the follow-up and ensure the management of the post-accidental phase and an as prompt as possible return to normal life.

Depending on the scope, the cells which compose the National Crisis Centre (Emergency and Coordination Committee, Evaluation Cell, Measurement Cell and Information Cell) participate in exercises of the emergency plans at the relevant facilities.

The Royal Decree of 1 March 2018 defines the emergency planning zones relative to the direct actions to protect the population (evacuation, sheltering, and iodine prophylaxis). The evacuation planning zones extend to a 10 km radius around the nuclear plants; the sheltering and ITB planning zones extend to 20 km around the nuclear plants.

The intervention criteria levels are set in the NEP. They are 5 mSv expected total effective dose integrated over 24 hours e.g. taking into account all direct exposure pathways (cloud shine, inhalation and ground shine) for sheltering, 50 mSv expected total effective dose integrated over 7 days (1 week), i.e. by taking into account all direct exposure pathways (cloud shine, inhalation and ground shine) for evacuation. For intake of stable iodine, the intervention reference levels are 10 mSv thyroid equivalent dose for children less than 18 years and pregnant or breastfeeding women and 50 mSv for adults.

For off-site radiological calculations, focusing on the urgent protective actions, the licensee has to implement a radiological assessment model. For that purpose, a dose/dispersion model developed by the Belgian Nuclear Research Centre (SCK•CEN) is used. The model is a segmented Gaussian plume model, based on the Belgian (also called Bultynck-Malet or SCK•CEN) turbulence typing scheme and the associated dispersion ('sigma') parameters [7]. These parameters were obtained using extended tracer experiments on each site during the sixties/seventies. The calculation domain extends up to 50 km around the release point. For the Tihange site empirical correction factors were introduced to take the more complex topography into account. Calculations are done per time step of 10 minutes, extrapolations (projections) over time can be made as well. In addition to the dispersion model, a set of standard scenarios has been developed in order to perform quick assessments at early stages. In the latest version of the diffusion model [8], the parameters associated with the standard scenarios have been stored in a database allowing rapid projections for any of the pre-defined scenarios. In addition,

[7] H. Bultynck and L.M. Malet, Evaluation of atmospheric dilution factors for effluents diffused from an elevated continuous point source, TELLUS Vol 24, N°5 (1972).

[8] A. Sohier, Expérience et évaluation des codes de calcul de doses actuels utilisés en temps de crise nucléaire, Annales de l'Association belge de Radioprotection, Vol 24, N° 4 (1999).

simplified and user friendly tools and models are available to the evaluation cell and FANC-Bel V for cross-check validations and/or specific projections.

The exposure pathways considered for urgent protective actions are cloud shine dose, inhalation dose and ground shine dose (instantaneous and integrated up to one day and two weeks). Ingestion pathway would be covered by implementing measures on the food chain (food ban...).

Effective doses for adults and thyroid doses for adults and children are calculated. Deposition of iodine (limited to I-131) and caesium (limited to Cs-137) are also calculated. Related to forecasts, the total doses as well as the projected doses are calculated.

The National Emergency Plan is continuously evolving and is worked on a permanent basis. This effort incorporates lessons learned from emergency exercises and aims at a steady progress in the development of standardized working procedures and tools for diagnostic purposes, radiation monitoring strategy and decision making.

c) Internal and External Emergency Plans for Nuclear Installations, Training and Exercises, International Agreements

The emergency plan of each Belgian unit is systematically described in its Safety Analysis Report (chapter 13, § II.I.3). In complement, an "internal emergency plan" details the instructions for all the actors.

In case of accident the unit's "Centre Opérationnel de Tranche" (COT - Tihange) – "Bedrijfskamer" (Doel) (i.e. the On Site Technical Centre) is activated and manages all the technical problems to control the accident and mitigate its consequences. At site level, the "Centre Opérationnel de Site" (COS - Tihange) – "Noodplankamer" (NPK - Doel) (i.e. the Emergency Operations Facility) manages the environmental impact, liaises with the National Crisis Centre, and communicates with the Corporate crisis Organization.

The nuclear power plants conduct internal exercises several times a year, and the Civil Protection and of Crisis Centre Directorates of the Home Affairs Federal Public Service (FPS) organise one internal and one external exercise annually for each nuclear power plant and every two years for other sites.

Consistent with the intended objectives, the FPS involves the various disciplines (fire brigade, medical help, police force, civil protection, measurement teams ...) in these exercises.

The operator is requested to draw up a scenario with which the objectives can be tested.

During the exercise, the information corresponding to the scenario is gradually forwarded to the various participants; the Training Centre full-scope simulator may in certain cases also be used on-line during exercise to provide information needed.

Information exchange at the international level is performed through the National Crisis Centre, which has contacts with the competent Authorities of the neighbouring countries, and which is the "national contact point" for Convention on Early Notification of a Nuclear Accident (IAEA) and for the similar European Union system (ECURIE).

Agreements also exist at local and provincial level. The protocol Agreement between the province of "Noord Brabant" (The Netherlands) and the province of Antwerp (Belgium) provides for a direct line between the alarm station of Roosendaal (The Netherlands) and that of Antwerp, informing it as soon as the notification level Site Area Emergency is decided. This direct line is also used when certain accidents occur in the chemical industry (installations within the scope of the European post-Seveso Directive). A direct information exchange can also take place between the alarm station of Vlissingen (The Netherlands) and that of Ghent should an accident occur at the Borssele nuclear power plant. For the Chooz B and Tihange power stations, there are agreements between the Prefecture of the Ardennes department (France) and the province of Namur (Belgium).

In the frame of the agreement between the Government of the French Republic and the Government of the Kingdom of Belgium about the Chooz nuclear power plant and the exchange of information in case of incidents or accidents, a mutual alarm is foreseen between the two countries in case of an accident occurring in the nuclear plants in Tihange, Chooz or Gravelines. This alarm takes place between the National Crisis Centre on the Belgian side and the "COGIC", ("Centre opérationnel de gestion interministérielle des crises") on the French side.

During the exercises of Chooz and of Gravelines that transborder collaboration is regularly tested at the local and national levels. In addition, a direct exchange of technical and radiological information takes place between the organisations in charge of the expertise (IRSN on the French side, Bel V on the

Belgian side) and in charge of the advice (Nuclear Safety Authority in France, Evaluation Cell of the National Crisis Centre in Belgium) and is quite successful. Based on these experiences, information exchanges have been developed as well as their implementation modalities between the French and Belgian parties involved with the view to be operational for further exercises and in case of incidents and accidents.

Regarding independent evaluation in the event of an emergency, Bel V sends a representative to that site and to the evaluation cell of the National Crisis Centre and activates its own emergency plan cell. This cell has dedicated telephone and facsimile lines to the affected installation and to the evaluation cell. Based on the technical information supplied directly by its representatives and all the information about the unit that it has at its head office, Bel V proceeds with a technical analysis of the situation, assesses the radiological consequences from the releases indicated in the scenario, and produces release forecasts from the estimated situation of the unit.

These evaluations of the consequences to the environment are made either with the same computer codes as those of the operator, or with tools developed in Bel V, so as to allow a validation of the results provided by the licensee. These various computer codes have been compared in terms of assumptions and calculation methodologies.

On April 28, 2004 an agreement was signed between Luxembourg and Belgium concerning the exchange of information in case of incidents or accidents with potential radiological consequences.

Table 10 gives an overview of some exercises (national and international) performed during the period 2016-2019 (only for the installations within the scope of the CNS):

Date	Site	Type	Objectives
17/02/2016	ConvEx 2a	International	Test of notification procedures (USIE).
15/03/2016	NPP Doel	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.
21-23/06/2016	ConvEx 2b	International	Test of notification procedures (USIE). Test of the coordination between NCA(D) and NCA(A).
05/10/2016	ConvEx 2d	International	Test of notification procedures (USIE). Test of the coordination of national assistance capabilities by NCA(A).
25/10/2016	NPP Tihange	National	Global exercise directed by controllers, with the participation of some response organisations and deployment of field intervention teams
28/02/2017	ConvEx 2a	International	Test of notification procedures (USIE).
28/03/2017	ECUREX	International	Test of notification and information exchange procedures.
21-22/06/2017	ConvEx 3	International	Test the full operation of the information exchange mechanisms.
21/11/2017	NPP Doel	National	Global combined safety-security exercise directed by controllers, with the participation of some response organisations and deployment of field intervention teams
24/11/2017	NPP Tihange	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.
07/02/2018	NPP Borssele (Regional)	bilateral	Participation to a Dutch exercise in order to test the bilateral agreement on information exchanges at different levels. Test of the HERCA/WENRA approach.
08/03/2018	ConvEx 2a	International	Test of notification procedures (USIE).
16/04/2018	NPP Borssele (National)	bilateral	Participation to a Dutch exercise in order to test the bilateral agreement on information exchanges at different levels. Test of the HERCA/WENRA approach.
08/05/2018	NPP Doel	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.
30/11/2018	NPP Tihange	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.

21/03/2019	NPP Doel	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.
28/03/2019	NPP Borssele (National)	bilateral	Participation to a Dutch exercise in order to test the bilateral agreement on information exchanges at different levels. Test of the exchange of technical and radiological information between homologous entities.
16/05/2019	NPP Tihange	National	Partial exercise, limited to the interaction and information exchange between the site emergency management team of the licensee and the federal evaluation cell CELEVAL.

Table 10 : Overview of EPP exercises for the period 2016-2019.

d) Lessons Learned from Emergency Preparedness Exercises.

Each year, an exercise with participation of the authorities is conducted at each NPP site (i.e; Doel and Tihange). Once every four years, this annual exercise takes the form of a so-called "methodologically accompanied exercise" in which all federal, provincial and local authorities participate. Such an exercise was conducted at Tihange on November 29th, 2016. For the preparation of these exercises, besides several preparatory meetings with different participants, a table-top exercise for the communication flux was held and specific training of nuclear and radiation risks were given to all participants. Main conclusions of this exercise can be summarised as follows:

- To render the exercise scenario more precise and stimulating, more people at local level should be involved in the preparation and execution of the exercise;
- For similar reasons, introducing (fictive) media pressure at all levels has been seen as very valuable;
- The presence of a senior level expert from the regulatory body within the federal coordination cell has been observed as very valuable;
- For communication issues, the importance of a centralised information system for all incident and crisis communication has been confirmed by the exercise.

Lessons learned from exercises with neighbouring countries have shown some difficulties with respect to alerts, exchange of technical and radiological data and expertise and communication. Following these observations, a specific working group was created to improve the collaboration between the local authorities of the different countries.

II.L.3. SCK•CEN (research reactors)

The general rules for emergency preparedness for the SCK•CEN installation are the same as for the nuclear power plants. The SCK•CEN has a central emergency control room, equipped with the necessary information and communication systems and is located in a building without major nuclear infrastructure. The SCK•CEN has one vehicle fully equipped for radiation measurements in emergency situations. The measurement capacity can be increased using a second vehicle with manual measurement equipment. These measurement teams are available to the national crisis centre.

The organisation of the internal emergency plan is described in a general procedure. For each of the groups involved in the emergency plan a task description is available. Standard accident scenarios are developed for the major nuclear installation. These must allow recognizing and communicating the essential information and the potential consequences to the national crisis centre. According to the Belgian national nuclear emergency plan, these scenarios can lead to the various notifications levels described in section a). The level General Emergency in 'reflex' mode, corresponding to the risk of a fast significant release of fission products, can only occur for BR2 in case of severe damage to the fuel combined with containment bypass.

Exercises are held, in cooperation with the authorities and the other nuclear facilities in the neighbourhood. Every year, another company simulates the accident and takes the lead in the exercise. The measurement teams take also part in the exercises of the nuclear power plants.

Beside the internal emergency plan, the SCK•CEN is also involved in the National Crisis Centre Experts participate in different evaluation cells.

II.L.4. Information of the Public

The GRR-2001 specifies in its Article 72 all the obligations regarding training and information of the public.

During the accident itself, information is supplied to the media by the information cell of the National Crisis Centre. At local level the provincial emergency plan includes the ways to inform the population (sirens, police equipped with megaphones, radio and television) and to follow-up the instructions given to the population (iodine tablets, sheltering, evacuation …).

II.M. Article 17. Siting

> Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:
>
> (i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;
>
> (ii) for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;
>
> (iii) for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;
>
> (iv) for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation

II.M.1. NPPs

a) Characteristics taken into Account in the Sites Selection

The Doel and Tihange nuclear sites were originally evaluated according to the requirements set by the US rules (Chapter 2 of the Safety Analysis Report, Standard Review Plan, 10 CFR 100).

These requirements apply to the phenomena of natural origin (earthquakes, floods, extreme temperatures…) and to the phenomena of human origin (industrial environment, transport…).

With regard to the natural phenomena:

- The geological and seismic characteristics of the sites and their environment were specifically investigated so as to identify the soil characteristics and the earthquake spectrums in order to define the design bases to be considered when dimensioning the structures and systems.
- The hydrological characteristics of the rivers Meuse (Tihange) and Scheldt (Doel) were surveyed, not only to quantify the risk of floods and possible loss of the heat sink, but also in order to develop the river flow models in order to assess the dilution of released liquid effluent.
- Meteorological and climatic surveys allowed defining the atmospheric diffusion and dispersion models to be used when assessing the short-term and long-term environmental impacts of atmospheric releases taking into account the local characteristics. These studies were complemented with demographic surveys in the vicinity of these sites.
- Concerning the population density around the sites, no detailed criterion was imposed originally. But the design of the installations made allowance for the existing situation: the "low population zone" of the USNRC rules is in fact within the site. Consequently, the radiological consequences of incidents or accidents are calculated for the critical group living at the site border or in any other location outside the site where the calculated consequences are the largest.
- Due to the very high source terms imposed by the U.S. safety rules, the design of the Belgian units incorporates strict limits on the containment leak rate (double containment with a steel liner for the primary containment) and systems to prevent liquid or gaseous leaks through the containment penetrations.

With regard to the external events of human origin:

- Due to the population density in the vicinity of the sites, and also considering the impact that the local industrial activities may have on the power stations, specific requirements were adopted in 1975: protection against external accidents such as civil or military aircraft crash, gas explosion, toxic gas cloud, major fire.
- The Tihange 2 and 3 and Doel 3 and 4 units were equipped with ultimate emergency systems aimed at automatically tripping the reactor, keeping it in hot shutdown during three hours so that after that period of time it may be possible to bring the unit to cold

shutdown and to remove residual heat, after a design basis external accident as referred to above, or during any loss of the normal control room or any of the systems that are controlled from it.

- These ultimate emergency systems are called "bunkered systems" as they are installed in specifically reinforced buildings. They comprise an autonomous protection and instrumentation system supplied with electric power from dedicated emergency diesel-generator sets, as well as primary make-up (water with boric acid to control the reactivity) and steam generator feedwater systems.
- Measures were also taken to guarantee the emergency heat sink in case of loss of ultimate heat sink (river). At the Tihange site, the preferred option was to bore wells from where groundwater can be pumped, whereas at Doel three artificial lakes were created.
- Following the 2001 September 11 events, ENGIE Electrabel and the Safety Authorities were brought to:
  - consider the eventuality of a voluntary aircraft crash on the Belgian Nuclear Power Plants,
  - identify which type of impact these plants would encounter,
  - determine the potential consequences of such impact,
  - consequently, adapt the in-depth defence strategy.
- From the studies performed on the potential consequences of an impact on each of the buildings of the plants of Doel and Tihange, it appears that:
  - the initial design of the last four units (Tihange 2 and 3 and Doel 3 and 4) is good: no perforation of the external containment even with a Boeing 767 at a speed of 150 m/s,
  - the initial design of the reactor buildings of Tihange 1 and Doel 1 & 2 is less resistant than those of the more recent units.
  - it is necessary to be able to fight a kerosene fire in order to avoid any damage to the structure of the building due to high temperature exposure. In consultation with the fire department and Bel V, new equipment was bought and is now operable (special firefighting truck with high pressure foam pumps) and are approved by the regulatory body.

b) Periodic Reassessment of the Site Characteristics

Reassessments are systematically performed during the periodic safety reviews of each unit.

During the 1st periodic safety review of Doel 1 & 2, as external accidents had not been considered in the initial design, additional emergency systems were installed in a reinforced building (the Bunker).

For the Tihange site, the safe shutdown earthquake originally considered (in the early seventies) for Tihange 1 was of 0.1 g acceleration. This value was increased to 0.17 g following the Tihange 2 safety analysis (end of the seventies). As a consequence, the latter value was adopted for the site as a whole; it did not need to be modified when the Liège earthquake of 1983 was analysed. The seismic reassessment of Tihange 1 was performed during its 1st periodic safety review in 1985.

This resulted in a considerable number of reinforcements being made in certain buildings, and in the seismic qualification of the equipment being re-examined (using the methodology developed by the US Seismic Qualification Utility Group).

Also, a review of the protection of Tihange 1 against external accidents was performed: the probability that an aircraft crash would result in unacceptable radiological consequences was assessed; taking into account the specificities of the buildings, that probability was found sufficiently low.

During the periodic safety reviews of each of the units, studies are performed and, where necessary, measures are implemented to ensure that the residual risk following external accidents remains acceptable taking into account the environment of the site with respect to the risks resulting from transport (including by aircraft) and from industrial activities.

The protection against potential floods at Tihange NPP was reassessed in the framework of periodic safety reviews as well as the possible rise in temperature due to climate change. This led to the decision to build a peripheral protection of the site, this action being conducted as part of the "Stress Tests" action plan (see below) and ended in 2015.

The protection against extreme external temperatures (heat wave, extreme cold) is currently being reassessed by ENGIE Electrabel in the framework of the action plan of the most recent periodic safety review of each unit.

c) *Stress Tests*

Following the Fukushima Daiichi accident, ENGIE Electrabel was asked to conduct Stress Tests. Safety evaluation reports for the Doel and Tihange sites have been established by ENGIE Electrabel and reviewed by the FANC and Bel V and external experts. Within the scope of the Stress Tests, an assessment of design bases, existing safety margins and cliff-edge effects was performed for the risks related to the Site Characteristics such as earthquake, flooding and bad weather conditions.

An action plan was launched as a result of the assessment, including:

- A probabilistic seismic hazard assessment for Doel and Tihange by ENGIE Electrabel (in collaboration with Royal Observatory of Belgium and external experts for peer review)
- A seismic safety margin assessment of the Structures, Systems and Components was performed.
- Reinforcements of Structures, Systems and Components to improve their resistance against beyond design earthquakes;
- A site peripheral protection for Tihange, in relation to an upgraded design basis flood;

Figure 16 : New peripheral protection of the site of Tihange

- Improvements of the protections against beyond-design-basis floods: in Doel, volumetric protections of sensitive buildings and adapted procedures; in Tihange, water supplies (involving pipes, pumps, additional electrical diesel generators, etc.) to the primary circuit, the steam generators and the spent-fuel pools, with adapted procedures and training;
- Improvements of the sewage systems for protecting the sites against rains with return periods much larger than considered in the design.

The status of the completion of the "stress tests" action plan can be found in section I.C.3.b) and leads, amongst others, to the confirmation that both sites are adequately protected against natural hazards, including flooding and earthquakes. As of end 2018, the review and assessment of the action plan by the regulatory body is nearly finalized.

d) WENRA RL2014

A global reassessment of natural hazards for both sites, in particular for Design Extension Conditions, is currently ongoing in the framework of an action plan launched to identify and resolve potential gaps in the implementation of the WENRA RL2014 at the NPPs (see also section I.C.3.e).

II.M.2. SCK•CEN (research reactors)

a) Characteristics taken into Account in the Sites Selection

The installations of the SCK•CEN are located in the north-east of the province of Antwerp, which is one of the lesser populated regions of the northern part of Belgium. This was one of the major reasons for the choice of the location, together with the availability of sufficient free terrain.

The site has a low risk for the occurrence of natural phenomena.

- The site is located far from major rivers or from the sea, in a flat sandy area, such that the risk of flooding is very limited. However, very local flooding with a height up to 0.3 meter is possible in case of heavy rain combined with melting snow. Protection is available against this kind of flooding;
- The closest active seismic fault is located at a distance of about 80 km. At the occasion of the periodic safety review conducted in 1996, a seismic assessment of BR2 was made using a reference earthquake with a free field magnitude of 0.1g. This resulted in strengthening of a few components. With the periodic safety review of 2006, a similar analysis was made for BR1. For the safety review as a consequence of the Fukushima Daiichi accident, the reference acceleration was increased and the resistance of the reactors was studied. Although both reactors rely on natural convection cooling in emergency situation it was concluded that an improvement of the back-up electrical power system would be useful in case of a severely damaged installation. In 2019 new diesel generators for the BR2 including a new housing were installed. Other activities on-site are ongoing to improve the electrical power system.

b) Stress Tests

Following the Fukushima Daiichi accident, all Belgian "Class 1" nuclear installations (including the power reactors and the research reactors), were asked to conduct Stress Tests. The safety evaluation report for SCK•CEN has been established by the licensee and reviewed by the FANC and Bel V. No peer review was foreseen.

In the frame of the Stress Tests, an assessment of design bases, existing margins and cliff-edge effects was performed in relation to risks related to the site characteristics like earthquake, flooding and bad weather conditions. A graded approach was used.

The FANC National report was issued on April 16, 2013. The action plan for SCK•CEN that consists of 42 actions was finalized and approved by July 2013. Most of these actions are implemented. Some major actions are not yet finished:

- Construction of a new network that provides water for firefighting;
- Improving the emergency electricity network.

II.M.3. International Agreements

The obligation to inform the neighbouring countries when planning a nuclear installation is stipulated in Article 37 of the Euratom Treaty, which is applicable in Belgium (cf. Article 6 of the GRR-2001). The reports drawn up to meet this requirement have been transmitted to the European Commission as provided for in the licensing procedures for the Belgian power plants. After consultation of the "Article 37" group of experts, the Commission issued a favourable advice for the sites of Doel and Tihange. Direct information of the neighbouring countries which might undergo notable consequences on their territory was an obligation deriving from the Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.

This European Directive has been superseded by the Directive 2011/92/UE on the assessment of the effects of certain public and private projects on the environment, which was amended by the Directive 2014/52/UE. This amendment was transposed in the Belgian legal framework by the Law of 6 December

2018 for the radiological part. The directive requires direct information and consultation of competent authorities of the neighbouring countries which might undergo notable consequences on their territory.

II.N. Article 18. Design and Construction

> Each Contracting Party shall take the appropriate steps to ensure that:
>
> (i) the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;
>
> (ii) the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;
>
> (iii) the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.

II.N.1. NPPs

The design, as well as the major modifications following the successive periodic safety reviews of the Belgian nuclear power plants is described in Appendix 1 to the present Report.

a) Rules followed during Design and Construction

The "Commission Spéciale des Radiations Ionisantes" (i.e. the Belgian nuclear Special Commission, now replaced by the Scientific Council of the FANC) decided in 1975 that the USNRC rules should be followed for the construction of the next four units (Doel 3 and 4, Tihange 2 and 3) and that some accidents of external origin should be considered in the design.

Accordingly, the design and safety analysis of these units have been done following the US NRC rules and all the associated documentation (regulatory guides, standard review plans, ASME Code, IEEE standards, ANSI, ANS, etc.) in order to ensure a consistent approach. 10 CFR 20 on radioprotection was not followed, as the corresponding topics were covered by the Euratom Directive on the Basic Safety Standards. Compliance with the withheld US NRC rules is documented in the Safety analysis Report, deviations are identified and justified. For non-mandatory rules, the Safety Analysis Report documents how they have been implemented, in compliance with the safety objectives.

For safety-related pressure vessels, a specific derogation to the Belgian pressure vessel regulations ("Règlement général pour la protection du travail") was elaborated, in order to allow the use of the US rule based ASME Code sections III and XI. A few components not covered by the ASME specifications but covered by the Belgian regulations had still to comply with the Belgian regulations. A transposition of the ASME Code has been written to cover organisational aspects like the definition of an inspector, of the Authorised Inspection Agency (AIA), etc …That transposition of the ASME Code clarifies also the conditions under which other construction or in service inspection codes (like French or German codes) can be used. Their equivalence must be justified, justification which must be agreed by the AIA and by Bel V.

As mentioned above, the Special Commission also required that accidents of external origin be considered (i.e. aircraft crash, gas explosion, toxic gases, large fire).

The protection against explosions was based on German rules. For the aircraft crash the bunkered structures were designed to resist the impact of a large civil airplane. It was also checked that the probability to go beyond the design criteria of the bunkered structures was smaller than 10^{-7} per reactor year. Toxic and explosive gas (external explosion) have also been considered and integrated in the design.

It has been shown that the probability to exceed the design criteria was, for each family of external accidents, smaller than 10-7 per reactor year and 10-6 per reactor year for all external accidents together. The residual risk that an external event leads to unacceptable radiological consequences for the public is a fortiori even smaller, as exceeding the design criteria for an external hazard does not necessarily lead to unacceptable radiological consequences in all cases.

b) Application of the Defence in Depth Concept

The defence in depth concept is an integral part of the Framatome or Westinghouse nuclear power plants designs and is also found in the US safety rules.

Accordingly, this concept has been systematically applied in all Belgian nuclear power plants.

Furthermore, the design of all the additional systems to address external accidents adhered to the same principles, and in particular the single-failure criterion was applied. Compared to a conventional-design pressurised water reactor nuclear power plant, the additional systems installed to mitigate the consequences of an external accident in fact strengthen considerably the third level of the defence in depth approach, as they can help during certain internal accidents which might develop unfavourably.

In the framework of periodic safety reviews, for all units, a global evaluation of the safety during low-power and shutdown states is performed.

c) Periodic Safety Reviews

The first periodic safety reviews took place in 1985 for the Doel 1 & 2 and Tihange 1 units. At the time of design of these units, i.e. in the early 1970s, the safety rules were less numerous and less detailed than they were for the later Belgian units that were started between 1980 and 1985. For instance, physical separation was less strictly applied, seismic and post-accidental qualification were less developed, the notion of high-energy line break did not apply to all systems, external accidents were not systematically considered.

The different subjects examined during these periodic safety reviews are detailed in Appendix 5.

These 1st periodic safety reviews were conducted very comprehensively and were an in-depth review of the safety of the nuclear power plants. This made it possible to identify coherent solutions and, at times, to simultaneously solve several problems (an example is the emergency building, i.e., the bunker, of Doel 1 & 2). It also demonstrated that it is even possible to improve strongly design- and lay-out dependent systems of the nuclear power plant: taking into account a higher-intensity earthquake, protection against external accidents, a new reactor protection system...

For instance, at Tihange 1, considering a design earthquake of 0.17 g acceleration (value of the Safe Shutdown Earthquake defined in the safety analysis of Tihange 2 and 3) instead of the original value of 0.1 g used in the design of unit 1, resulted in recalculating with much more elaborate methods the seismic behaviour of all the buildings, and strengthening a number of structures. Also, the resistance to earthquake of many equipment and components had to be reviewed, based on feedback from experience with equipment which had undergone a real earthquake. Similarly, external accidents due to human activity were considered. Other fields included protection against high-energy line breaks, protection against primary system overpressure, improvement of fire protection, improvements of the reliability of systems, more effective training of operators (training centres with several simulators), improvements to the man-machine interface, systematic utilisation of both national and international feedback of operating experience.

Similar steps were followed for Doel 1 & 2. In the design and during the construction of Doel 1 & 2, earthquakes had not been considered as a factor influencing the design requirements, due to the weak seismic activity of the region. For Doel 3 and 4, applying the USNRC rules has imposed a minimum of 0.1 g for the Safe Shutdown Earthquake (SSE). For Doel 1 & 2, the same methodology for defining the SSE has been followed, except the requirement of a minimum value of 0.1 g. The resulting SSE retained for the design has an acceleration of 0.056 g.

As for Tihange 1, this led to a check of the resistance of buildings and equipment. Moreover, to cope with accidents of external origin, a bunkered and seismically resistant building has been erected, containing so-called emergency safeguard systems, which allow maintaining primary water inventory, ensuring reactor sub-criticality and residual heat removal and coping with accidents like a fire in the electrical auxiliaries building (including the loss of the main control room), the total loss of electric power (external grid and the safety Diesels), the SSE, a high-energy line break.

In this way the safety level of these units was raised towards a level closer to that of the most modern units. All the analyses were conducted according to deterministic safety rules and complemented with reliability analysis of the various systems.

The 1st periodic safety review of the most recent units (Doel 3 and 4, Tihange 2 and 3) and the 2nd periodic safety review of Doel 1 & 2 and Tihange 1 did not require reviewing the design bases, since post-TMI actions had already been taken into account and there had been no major evolution in the regulations during that period.

During these safety reviews, national and international feedback were examined; the results of probabilistic safety studies made for power operation or for shut down states were taken into account, the severe accident consequences were analysed in order to infer prevention and mitigation measures, structural and equipment ageing were evaluated, as well as qualification problems, and the field of accidents that are considered as design-basis accidents was broadened. The PSAs and the analyses of severe accidents resulted in the installation of (autocatalytic) hydrogen recombiners inside the reactor containment for all units.

The second periodic safety reviews of the most recent units (Doel 3 and 4, Tihange 2 and 3), and the third periodic safety review of the oldest ones (Doel 1 & 2, and Tihange 1) include two sets of topics: the first one is made of topics common to all units ("fleet approach"), the second one addresses aspects specific to one unit.

All these periodic safety reviews included two parts: one part "studies", another part "implementation" of the results of the studies, which led to a large number of modifications on the first Belgian units.

The third periodic safety reviews of the most recent units (Doel 3 and 4, Tihange 2 and 3), and the fourth periodic safety review of the oldest ones (Doel 1 & 2, and Tihange 1) were performed according to IAEA Guide NSG-2.10. As far as Doel 1 & 2 and Tihange 1 are concerned, they included an LTO-approach. Due to the evolving context (e.g. post-Fukushima action plans), almost no hardware modifications resulted directly from those periodic safety reviews, which are more focused on the evaluation of the processes to manage safety and its results.

d) Accident Prevention and Mitigation of Consequences

Accident prevention and mitigation of consequences are basic principles adhered to in the design of Belgian nuclear power plants.

In case of disturbance in the operation parameters of the plant, the control system will respond in order to bring the plant back to its nominal operation point.

In case of risk of reaching the safety limits, the reactor protection system will shut down the plant.

The engineered safety systems are activated to address the design basis accidents and achieve the safe shut down of the plant.

Consistent with the standard format of the Safety Analysis Report, all the instrumentation and control systems are described in chapter 7, and incident and accident analyses are discussed in chapter 15.

The four more recent Belgian units (Doel 3 and 4, Tihange 2 and 3) are three-loop 1 000 MWe units that are designed with three independent safety trains (instead of two interconnected trains in a traditional design).

Apart from the Doel 1 & 2 units, in which the primary containment is a metal sphere, the primary containment of all other units is a prestressed concrete structure with on the inside a steel liner. The secondary containment is in reinforced concrete at all units. The annular space between the two containments is put at negative pressure, so as to collect possible leaks after an accident. There is an internal recirculation and filtration system in the annular space and the air is filtered again prior to release via the stack.

During the 90's, probabilistic safety studies were carried out for all the Belgian units. These studies were either level 1 with analyses of scenarios that could present a risk to the containment integrity, or level 2 studies (in this case with no source term calculation). PSA studies are now required by article 29 of the SRNI-2011.

These studies considered reactor operation at power as well as in shut down states.

The results showed, among other, the value of having protection systems against external accidents. Indeed, these systems can act also in the event of failure of the traditional engineered safety systems; this considerably reduces the probability that certain initiating events could develop to the point of contributing to a core melt.

The update of all PSAs led to full Level 2 analyses for all representative plants, for power and shutdown states. A level 1 Fire and Flooding PSA has been performed for all units and a level 2 Fire and Flooding PSA for a representative unit. The most recent and the ongoing developments in the field of PSA are discussed in section I.C.5.b).

Apart from PSA studies, severe accident management guidelines have been introduced at all Belgian plants in order to strengthen the 4th level of defence-in-depth. They are subjected to periodic reviews. All Belgian plants dispose of adequate emergency operating facilities, in order to cope with major accidents, according to the principles of Defence-In-Depth. "Stress tests" also led to plant modifications, increasing the robustness of the plant with regard to extreme natural phenomena

e) Application of Proven or Qualified Technologies

The safety-related structures, systems and components are subject to qualification programmes to the environment in which they are situated and operated (normal, test, incident, accident). The same is applied regarding seismic qualification. The programmes are described in the sections 3.10 and 3.11 of the Safety Analysis Report and are consistent with the relevant US rules. Significant efforts have been made in this field, with tests in large qualification loops or on high-capacity seismic tables.

The results of all these tests are included in the "Manufacturing Records" of the qualified equipment and are summarised in synthetic reports for later use.

For the design codes used by vendors or architect-engineers, audits are conducted by Bel V to verify the qualification file and to examine the experimental bases on which the models and correlations of the code are founded.

Particular attention is given to verify and validate the design code itself and the quality assurance programme applied to the use of the code

f) Requirements of Reliable, Stable and Easily Controllable Operation, taking into Account Human Factors and the Man-Machine Interface

In order to make the operation of their power units easier and to increase their availability, the Belgian operator frequently applies the redundancy principle even to the normal control functions, so as to avoid spurious signals in the event of a failure. Similarly, they install additional components in standby that can be quickly started or connected, so as not to have to shut down the power station in the event of significant unavailability of the first components.

In the control room, operators are informed through display and alarm windows as soon as possible of any operational anomaly of the power station. The alarm windows have been colour-coded according to their importance. Normal operation and safeguard system panels are separated as much as possible.

A process computer is available for the operator, with dedicated pre-formatted screens to follow up particular system variables, or with alarm logs. Alarm sheets are available in the control room for each alarm, indicating to the operator the significance of the alarm, its origin (and possible causes), the automatic actions possibly initiated and the manual response, if any, that is required from the operator.

As a post-TMI action, following NUREG 0737, the control room and its ergonomics were reassessed. The instrumentation used for post-accidental operation was identified more clearly, and the notion of SPDS (Safety Parameter Display System) was implemented in the control room (or in a room adjacent to it).

In case of unavailability of the main control room (for example inacceptable habitability) a Remote Safety Panel, located in the bunker control room for the last four units or in an appropriate building for the older ones, is fitted with all the controls of the main systems necessary for bringing the reactor to cold shutdown. A specific set of procedures for the remote panel is present in the bunker control room (or equivalent location).

Moreover, the bunker control room and the bunker specific equipment have the capability to bring the reactor to a safe state (fallback state) and to go safely to cold shutdown, in case of an accident of external origin (aircraft crash, explosion and/or large fire). Procedures covering these cases are also available in the bunker control room (or equivalent location).

In the probabilistic safety studies, the tasks expected from the operators are detailed and modelled during the accident as well as during the post-accidental phase when the safe status of the unit is being restored. Following this critical review, the existing procedures can be amended to increase their efficiency and ease of use, or new procedures can be written (for instance for the non-power states).

II.N.2. Research Reactors

The reactors BR1 and BR2 were designed and constructed between 1952 and 1962, before a dedicated nuclear regulation existed in Belgium. The reactors were licensed according the regulations on industrial installations. This licence was amended several times, with specific requirements for nuclear installations. In 1986 the old licence was replaced by a new one, a Royal Decree based on the actual nuclear safety regulations.

The design of the BR1 is based on the reactors X-10 of ORNL, USA and BEPO of UKAEA, Harwell. The reactor was designed for a thermal power of 4 MWth. Since 1965, the maximum thermal power has not exceeded 1 MWth and since a few years, the power is limited by licence to 1 MWth. This allows working with the auxiliary ventilation only and avoids the accumulation of Wigner energy in the graphite. During the lifetime of the reactor no major modifications were made.

The design of BR2 is rather unique. The reactor is designed to produce a high neutron flux (thermal and fast), without being a fast sodium cooled reactor. The design has never been repeated. A reactor that is comparable is the ATR reactor of Idaho National Laboratory, USA. The original design thermal power of BR2 was 50 MW. In 1973 the primary heat exchangers were replaced in order to allow a thermal power of more than 100 MW. However, this thermal power is not the limiting factor as long as the heat can be evacuated without a too high temperature on the fuel plates. The power of the reactor is limited by the fact that the maximum heat flux on the fuel plates must be lower than 470 W/cm² in routine operation and 600 W/cm² for special experimental conditions.

Both reactors were included in the complementary safety analysis after the Fukushima Daiichi accident. As a conclusion of the analysis, a number of design upgrades were installed.

II.O. Article 19. Operation

> Each Contracting Party shall take the appropriate steps to ensure that:
>
> (i) the initial authorisation to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;
>
> (ii) operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;
>
> (iii) operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;
>
> (iv) procedures are established for responding to anticipated operational occurrences and to accidents;
>
> (v) necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;
>
> (vi) incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;
>
> (vii) programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organisations and regulatory bodies;
>
> (viii) the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

II.O.1. NPPs

a) Initial Authorisation and Commissioning

For the 7 operating NPPs, the Royal Decree of Authorisation was signed by the King after it has been examined in detail by an AIO (AVN, now Bel V), the "Commission Spéciale Radiations Ionisantes" (now replaced by the Scientific Council of the FANC) and the Safety Authorities (now the FANC).

The commissioning test programme was discussed and approved by the AIO (AVN), which followed the tests, evaluated the test results, verified the conformity to the design and issued the successive permits that allowed proceeding with the next step of the test programme.

This process was complete when the AIO (AVN) authorised the operation of the unit at full power.

b) Operational Limits and Conditions

As described before, the Technical Specifications are approved in the frame of licensing (chapter 16 of the Safety Analysis Report). They specify the operational limits and conditions, the availability requirements of the systems, the tests and inspections, and the actions to be taken if the acceptance criteria are not met. This applies to any state of the nuclear power plant. Extensive backgrounds of the Technical Specifications exist and are available to the personnel.

There are procedures related to compliance with the Technical Specifications for maintenance activities during plant outage and plant operation. Technical Specifications requirements and limitations are explicitly addressed in the maintenance procedures. Independent checks of the strict compliance with Technical Specifications during outages are carried out, both in the preparatory outage activities (work planning) as well as during the outage itself. These checks relate to equipment as well as to safety-related functions, like the integrity of the containment during refuelling, verification of the redundancy of the heat removal systems during RHR operation, …

Modifications of the installations with a potential impact on nuclear safety must be approved by the Health Physics department before it can be implemented, as explained in Article 14, section II.J.1.c).

In this respect, changes of procedures, of the Technical Specifications and of the Safety Analysis Report are identified and discussed.

c) Procedures for operation, maintenance, inspection and testing

A general description of the operation procedures is given in section 13.5 of the Safety Analysis Report.

The completeness (in format and contents) of the procedures has been examined based on Regulatory Guide 1.33 which lists the subjects for which procedures must be established. This examination was conducted in the scope of licensing and acceptance of the installations by AVN.

During the commissioning tests, the relevant procedures that were used by the operators were verified for adequacy.

Document management is based on ENGIE Electrabel guidelines and on the Internal Code for Nuclear Safety. Documents are classified into the following categories: policy-related procedures, operational procedures, instructions, supporting documents, help documents and witness documents. For policy-related procedures, operational procedures and instructions, more strict handling requirements have been established.

d) Incident and Accident Procedures

A full set of incident and accident management procedures has been developed by ENGIE Electrabel, with the help of the Architect Engineer and the designer of the Nuclear Steam Supply System. These procedures cover both power operations and shutdown modes.

These procedures are validated on a simulator and are used for operator training. Procedures are periodically reviewed and relevant experience feedback is integrated. Procedures backgrounds have been developed for some normal and incident procedures.

The Belgian NPPs, except Tihange 1, have implemented the Emergency Response Guidelines (ERG) approach developed by the Westinghouse Owners Group (WOG). These standard procedures have been adapted to the plant-specific elements and systems, especially the systems for protection against external events.

The ERG procedures are composed of 3 major elements: (1) the optimal recovery procedures (ORG: optimal recovery guidelines) which are event-based, (2) the critical safety function status trees and (3) the function restoration procedures (FRG: function restoration guidelines) which are both symptom-based, i.e. independent of the event scenario.

The ORG procedures, based on event scenarios with a probability of occurrence greater than 10^{-8}/y, have as main objective to recover the plant and to bring it back to a known safe state (in general the cold shutdown with the RHR system connected). ORG procedures are characterized by a response directly connected to event scenarios, by a preliminary diagnostic and by a constant diagnostic within each specific procedure in order to allow possible reorientation.

The critical safety function status trees explicitly identify the status of the safety functions independent of the event scenario. The trees prioritize challenges to these functions and identify the appropriate FRG procedure to be used to respond to these challenges. The 6 defined critical safety functions are: subcriticality, core cooling, heat sink, integrity of the primary system, containment and primary water inventory.

The FRG procedures are used to restore any challenged critical safety function.

The ORG on one hand and the status trees and the FRG on the other hand are applied in parallel during an event: the first procedures are used by the operator's crew (event-based approach) whereas the second ones are applied independently by a Shift Technical Adviser (symptom-based approach).

In conclusion, event-based and symptom-based procedures are used in parallel in Belgium by the NPP staff. The combination of a redundant approach (ORG <> FRG) associated with a human redundancy (operators crew <> shift technical adviser) allows to cover a larger scope of events, ensuring an optimized response for simple event scenarios.

Specific procedures have been written to give guidance to the operators after an earthquake that could occur during normal operation or in shutdown state.

Severe accident management procedures, inspired by the "Severe Accident Management Guidelines" developed by the Westinghouse Owners' Group, were implemented, adapted to the specificities of each unit. The training programme of the control room operators was developed in parallel.

For Tihange 1, the Framatome approach has been followed. The accident management procedures combine event-based and symptom-based approaches, using the surveillance of key safety functions or parameters.

Severe accident management procedures were developed like in the other units, on the basis of the Westinghouse Owner's Group Guidelines.

e) Engineering and Technological Support

The organisation and know-how of the operator, described in chapter 13 of the Safety Analysis Report, must be maintained throughout the useful life of the power station, and even after its definitive shutdown as long as this new status is not covered by a new licence.

The Engineering Department has the overall responsibility for the Technical Support Process. However, technical support activities are decentralized into several surveillance programmes, each programme being under the leadership of the department having the most comprehensive knowledge of the particular process. The allocation of technical support functions between the different site departments and external organizations is clearly established. The Engineering Department also acts as design authority.

The divisions of the Engineering Department at the corporate level also provide technical support to the sites. These corporate divisions are, amongst others, in charge of the management of the periodic safety review, of large-scale projects common to Doel and Tihange and their coordination, of the monitoring of the ageing projects and of specific safety projects.

Some technical support activities are carried out in partnership with Tractebel ENGIE. A new and reinforced partnership agreement was signed in 2019. This agreement defines an exclusive and systematic collaboration for all services needed by ENGIE Electrabel in the identified areas of collaboration. Examples of these identified areas are safety and licensing studies, fuel and core management, FSAR update management, QA supplier qualification, plant life management studies, expertise in nuclear construction and inspection codes. If certain activities in these identified areas are to be performed by other companies, this will be a joint decision between ENGIE Electrabel and Tractebel ENGIE.

Tractebel ENGIE has been in charge of the studies and their implementation during the periodic safety reviews, which take place on a periodic basis, of the steam generators replacement projects, power increase projects and of a large part of minor modifications projects, which allowed to maintain competence and knowledge of the installations. Tractebel ENGIE has also been participating in an integrated way to large programs like the Stress Tests (analysis and realization), the Long Term Operation project for the oldest plants, and the conformity with the WENRA Reference Levels... Tractebel ENGIE is also in charge of the follow-up of the provisioning of fuel reloads and of core management. Through its R&D projects, training actions and technological surveys, Tractebel ENGIE maintains a high competency in conformity with the state of the art. In order to reach these goals, Tractebel ENGIE participates in international research projects and is a member of various networks (or competency centres).

The design bases of the plants, i.e. the knowledge of the design of the plants and the reasons of the choices made in this design are an important part of the knowledge.

f) Notification of Significant Events

A technical regulation of the FANC of 5 July 2019 determines the criteria and modalities for notification of events and the use of INES.

This technical regulation replaces a convention between the Licensees, the FANC and Bel V. As the convention did before, this technical regulation stipulates in which circumstances and how INES is to be used. As explained in section I.C.7, the licensee has to perform an INES-analysis according the latest INES manual, and this level has to be approved by Bel V and by the FANC. Depending on the INES-level, a specific notice is issued.

Section 16.6 of the Safety Analysis Report lists the events that must be notified to Bel V and to the FANC, indicating the deadline for each notification.

The same section also specifies the cases where incident reports must be supplied to Bel V, and within which time period. In function of the significance of the events, the time period ranges from immediately to a month.

IRS reports are established by Bel V for the incidents it considers interesting for the international community.

Near misses are handled through the operational experience feedback process.

g) Operational Experience Feedback

At ENGIE Electrabel, Operating Experience is supported in all activities and at all levels of the organization. Operating Experience is part of the ENGIE Electrabel's continuous improvement programme.

A policy for operating experience has been established at ENGIE Electrabel. Comprehensive programmes have been set up for detecting, processing and communicating operating issues in order to optimize the use of international, national and local experiences in operating nuclear power plants.

The Operating Experience (OE) process can be initiated by different input triggers:

- An event inside or outside the operating organization. An event is defined as any unwanted, undesirable change in the state of plant structures, systems, or components or in human/organizational conditions (health, behaviour, administrative controls, environment…) that exceeds established significance criteria.
- Findings from audits and self-assessments
- Findings from the task observation programme
- Findings from post job debriefings
- Ideas, insights with a potential to significantly improve plant performance.

The OE programme results in:

- Immediate corrective actions,
- Medium and long-term corrective actions and/or improvements.

The OE feedback programme interacts on different levels of issues, events and ideas throughout the organization:

- Events and near misses: these are events and issues that require a stringent, formal approach by means of event reports.
- Low level events: these are events, issues and good practices that are revealed during the task observation programme and post job debriefings. These inputs are used for immediate actions as well as for annual self-assessments.

In parallel, different learning cycles exist to ensure learning from internal and external faults and strengths. Operating experience input coming from different sources is bundled in order to reveal relationships that lead to identifying and eliminating error precursors and flawed defences and their underlying organizational weaknesses. The main goal of this exercise is not merely counting events but pattern recognition. This OE feedback occurs in five loops and findings of lower loops are used as input for higher loops:

- Loop 1: immediate feedback, corrective actions, direct solutions and coaching.
- Loop 2: tri-monthly feedback of the performed observations (number, spread, quality) to different teams and services.
- Loop 3: annual self-assessments by the operational and maintenance teams. This bottom-up approach, supported by the immediate management, aims to define the next year's focus on different domains (technical, training, human performance, …).
- Loop 4: annual self-assessments and management reviews on intermediate level (within departments and/or services) aim to identify improvement areas on a (sub)process or organizational level and to identify weak points by systematically comparing real process outputs with management expectations, requirements of the regulator and authorities, and expectations from the nuclear sector. Per department a more hierarchical or transversal, horizontal approach is chosen.
- Loop 5: annual management reviews on fleet level of each process.

The information related to operating experience is accessible to all plant personnel, both on the intranet and in the document management system. The use of the available operating experience information is integrated into the different department processes and methods, in order to evaluate their own performance, to identify hidden weaknesses and to pro-actively avoid events

II.O.2. Research Reactors

a) *Operational Limits and Conditions*

The operational limits and conditions are described in the respective safety analysis report. A number of basic OLCs are defined in the licence.

The OLCs for the BR1 are:

- The maximum temperature of the cladding of the fuel,
- The maximum temperature of the graphite,
- The maximum burn up of the fuel and
- The maximum death time of the control rods.

The Wigner energy stored in the graphite moderator is measured on regular basis and serves to define the maximum temperature in the graphite.

The OLCs for the BR2 are:

- the tightness of the containment building,
- the maximum allowed fluence of the control rod guide tubes,
- the maximum allowed heat flux on the fuel plates and
- the maximum allowed fluence of the beryllium matrix.

Further OLCs are detailed in the safety analysis report of the reactors. There is a significant difference between these two types of OLCs. Those mentioned in the licence cannot be changed without a licence amendment. This requires a Royal Decree. An OLC formulated in the safety analysis report can be changed according to the designated procedures for modifications.

b) *Modifications*

The categorization and the treatment of modifications are similar to those for NPPs. The SCK•CEN developed a procedure for the practical treatment of modifications. This procedure is valid for all the installations, including the reactors BR1 and BR2.

The number of modifications for the BR1 is very limited. The general SCK•CEN procedure for modifications is used. An important modification must be submitted to the internal SCK•CEN advisory committee for the safety of installations. For modifications of the BR2, there is a dedicated procedure. All requests are submitted to an internal committee for approval. During the meeting, the decision whether the modification is significant or not is also taken.

Experiments are not considered as modifications and a dedicated approval procedure exists. For the BR1, new experiments are approved by the health physics department, in some cases following an advice of the SCK•CEN committee on the safety of installations. All information is transmitted to Bel V. The experiments for the BR2 have to follow a specific three stage approval (principle, design and construction). A fourth stage is also foreseen to integrate experience feedback including any problems that occurred.

c) *Reporting of Events*

The criteria and modalities for reporting unusual are determined in a technical regulation of the FANC (Technical Regulation of 5 July 2019). A number of criteria about the delay time for communicating events are defined. Belgium is also member of the Incident Reporting Systems for Research Reactors. A number of events regarding the BR1 and the BR2 are reported in the IRSRR. At BR2, a non-conformity report (NCR) is issued and stored in a database for all deviations from normal operation. Every person working at the installation has the authorization to compose such a report. It is discussed in the daily operators meeting and a decision is taken for follow up. All NCRs are reported to Bel V and discussed in the monthly meeting. Besides this reporting, there is also guidance of the FANC on the use of the INES scale for the SCK•CEN installations.

d) *Documentation*

The design and construction of both the BR1 and the BR2 date from more than 50 year ago. All persons having knowledge about the original design of the reactors have gone. For BR2 a Plant Asset Management Program (PAM) was started. One of the objectives of the PAM is to collect all information (design specification, drawings, commissioning tests, periodical test, repairs) about the listed assets. and to define an inspection, repair and replacement strategy for future operation. In case original components are no longer available, potential replacement components are defined that have an equivalent functionality. The program is defined is such way that the highest priority is given to components which are important to nuclear safety. An equivalent program for BR1 is under development.

e) Maintenance

For the BR1, a yearly maintenance plan is foreseen. This maintenance is mainly focused on the control rod mechanisms and the ventilation system, including the air filters. Beside this maintenance a two monthly inspection plan is executed. For BR2, the maintenance is done during the longer shutdowns. For every shutdown a detailed task plan is made. The list of tasks comprises repairs, preventive regular maintenance and modernization of components which were approved as modification. During the shutdown for replacement of the beryllium matrix major maintenance works were done.

II.O.3. Generation of Radioactive Waste

See the Belgian national report in the frame of the Joint Convention (October 2014) : https://afcn.fgov.be/fr/system/files/joint-convention-rapport-be-2017-final-noannex.pdf

II.O.4. Temporary Storage of Used Fuel

See Appendix **Error! Reference source not found.** and **Error! Reference source not found.**, and also the Belgian national report in the frame of the Joint Convention (October 2017).

Appendix 1. Description of the Nuclear Installations: Power Plants

Appendix 2. Description of the BR1 and BR2 Research Reactors

Not included in this version

Appendix 3. List of Acronyms

AFW	Auxiliary feedwater system
AIA	Authorised Inspection Agency.
AIO	Authorised Inspection Organisation.
ALARA	As Low As Reasonably Achievable.
ANS	American Nuclear Standards.
ANSI	American National Standards Institute.
ASME	American Society of Mechanical Engineers.
ASSET	Assessment of Safety Significant Events Team (IAEA).
ATLAS	Advanced Thermal-hydraulic test Loop for Accident Simulation (NEA/OECD).
AVN	Association Vinçotte Nuclear.
BDBE	Beyond Design Basis Earthquake
BIP	Behaviour of Iodine Project (NEA/OECD).
BS	Basic Standards.
CFD	Computational Fluid Dynamics.
CGCCR	Comité Gouvernemental de Coordination et de Crise, (i.e. the Governmental. Centre for Co-ordination and Emergencies).
CIPR/ICPR	Commission Internationale de Protection Radiologique (i.e. International Commission for Radiological Protection).
CNRA	Committee of Nuclear Regulatory Activities (NEA/OECD).
CNT	Centrale Nucléaire de Tihange (i.e. Tihange Nuclear Power Plant)
CSARP	Cooperative Severe Accident Research Program (USNRC).
CSNI	Committee on the Safety of Nuclear Installations (NEA/OECD).
CW	Cooling water pipes
DBE	Design Basis Earthquake
DENOPI	Spent fuel pool loss-of-cooling and loss-of-coolant accident project (IRSN).
ECURIE	European Community Urgent Radiological Information Exchange.
EDF	Electricité de France.
EDG	Emergency Diesel Groups
ENSREG	European Nuclear Safety Regulators Group
EU	European Union.
EURAD	European Joint Programming on radioactive waste management and disposal (Horizon2020/EC).
FANC	Federal Agency for Nuclear Control.
FASTNET	FAST Nuclear Emergency Tool (Horizon2020/EC).
FBFC	Franco-Belge de Fabrication de Combustible (i.e. Franco-Belgian Company for Fuel Manufacturing).
FINAS	Fuel Incident Notification and Analysis System (NEA/OECD).
FIRE	Fire Incidents Records Exchange (NEA/OECD).
FPS	Federal Public Service
FRAREG	FRAmatome REGulators
FRG	Function Restoration Guidelines.
FSAR	Final Safety Analysis Report.
GRR-2001	General Regulations regarding the protection of the public, workers and the environment against the hazards of ionizing radiation, laid down by Royal Decree of 20 July 2001
GRR-1963	General Regulations regarding the protection of the public, the workers and the environment against the hazards of ionizing radiation, laid down by Royal Decree of 28 February 1963.
HPD	Health Physics Department.
IAEA	International Atomic Energy Agency.
I&C	Instrumentation and Control
IEEE	Institute of Electrical and Electronics Engineers.
INES	International Nuclear and Radiological Event Scale (IAEA).

INPO	Institute of Nuclear Power Operations.
INSAG	International Nuclear Safety Advisory Group.
IRE	Institut des Radio-éléments.
IRRT	International Regulatory Review Team (IAEA).
IRS	Incident Reporting System (NEA/OECD-IAEA).
KCD	Kerncentrale Doel (i.e. Doel Nuclear Power Station).
MOX	Mixed-oxide U02-Pu02.
MUSA	Management and Uncertainties of Severe Accident (Horizon2020/EC).
NCM	Non-conventional means
NDA	Non Destructive Analyse.
NDTT	Non-destructive Testing Technology.
NEA (OECD)	Nuclear Energy Agency (OECD).
NERS	Network of Regulators of countries with Small nuclear programmes
NORM	Naturally Occurring Radioactive Material.
NPP	Nuclear Power Plant.
NRWG	Nuclear Regulators Working Group.
NUSS	Nuclear Safety Standards programme (IAEA).
NUSSC	Nuclear Safety Standards Committee (IAEA).
ODOBA	Observatory of the durability of reinforced concrete structures (IRSN).
OEF	Operational Experience Feedback.
ONDRAF/NIRAS	Organisme National pour les Déchets Radioactifs et les Matières Fissiles Enrichies/ Nationale Instelling voor Radioactive Afval en verrijkte Splijtstoffen (i.e. Belgian Agency for Radioactive Waste and Enriched Fissile Materials).
ORG	Optimal Recovery Guidelines.
ORNL	Oak Ridge National Laboratory
OSART	Operational Safety Review Team (IAEA).
PAMS	Post-Accident Monitoring System.
PKL	Primary coolant loop test facility (NEA/OECD).
PRISME	Fire Propagation in Elementary, Multi-room Scenarios (NEA/OECD).
PSHA	Probabilistic seismic hazard analysis
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
Q.M.	Quality Monitored.
RASSC	Radioprotection Safety Standard Committee.
R.D.	Royal Decree.
RGPT	Règlement Général pour la Protection du Travail (i.e. Belgium's Occupational Health & Safety Regulations).
RHR	Residual Heat Removal.
RHRS	Residual Heat Removal System.
ROB	Royal Observatory of Belgium
RPV	Reactor pressure vessel
R2CA	Reduction of Radiological Consequences of design basis and design extension Accidents (Horizon2020/EC).
SAM	Severe accident management
SAMG	Severe accident management guidelines
SBO	Station black-out
SCK•CEN	Studiecentrum voor Kernenergie, Nuclear Research Centre / Centre d'Etude de l'Energie Nucléaires, situated at Mol, Belgium.
SENA	Société d'Energie Nucléaire Franco-Belges des Ardennes.
SFP	Spent fuel pool
SG	Steam generators
SPDS	Safety Parameter Display System.
SPRI	Service de Protection contre les Radiations Ionisantes (i.e. Department of Protection against Ionising Radiation).
SSCs	Structures, systems and components

SSE	Safe Shutdown Earthquake.
STA	Shift Technical Advisor.
STAR	Stop-Think-Act-Review.
THAI	Thermal-hydraulics, Hydrogen, Aerosols and Iodine Project (NEA/OECD).
TMI	Three Mile Island.
TRANSSC	Transport Safety Standard Committee.
TRC	Technical Responsibility Centre (Bel V).
USNRC	United State Nuclear Regulatory Commission
VGB	Vereinigung der Grosskesselbetreiber
WANO	World Association of Nuclear Operators.
WASSC	Waste Safety Standards Committee (AIEA).
WENRA	Western European Nuclear Regulator's Association.

Table 11 : List of Acronyms

Appendix 4. List of the Web Sites of the Different Nuclear Actors in Belgium

4.A. Regulatory Body

Federal Agency for Nuclear Control:	http://www.fanc.fgov.be	(site in French and Dutch)
Bel V	http://www.belv.be	(site in French, Dutch and English)

4.B. Licences, Architect-engineers, Research Centres

ENGIE Electrabel:	http://corporate.engie-electrabel.be/	(site in French, Dutch and English)
Tractebel ENGIE :	http://www.tractebel-engie.com/	(site in English)
SCK•CEN:	http://www.sckcen.be	(site in English)
Belgoprocess:	http://www.belgoprocess.be	(site in English)
ONDRAF/NIRAS:	https://www.ondraf.be/	(site in French, Dutch, English and German)
AIB-Vinçotte	https://www.vincotte.be/en_be/home/	(site in French, Dutch and English)

4.C. Associations

Belgian Nuclear Society:	http://www.bnsorg.eu/	(site in English)
Belgian Association for Radiation Protection (BVS/ABR)	http://www.bvsabr.be	(site in French and Dutch)

4.D. Others

WENRA (Western European Nuclear Regulators Association	http://www.wenra.org
ENSREG (European Nuclear Safety Regulators Group)	http://www.ensreg.eu
HERCA (Heads of the European Radiological Protection Competent Authorities)	http://www.herca.org/

Appendix 5. Subjects examined during the Periodic (ten yearly) Safety Review

5.A. Subjects examined during the First Safety Reviews of the Doel 1 & 2 and Tihange 1 Units

The following subjects have been examined:

- protection against accidents of external origin and industrial risks
- re-definition of the design earthquake
- high-energy line break
- fire protection
- flooding, of internal or external origin
- high winds and extreme climatic conditions
- differential settlement between structures
- systems having safety-related functions to shut down the reactor, for core cooling and for evacuation of residual power:
    - reactor protection system
    - safety systems: emergency feedwater supply to the steam generators,
    - shutdown cooling system, safety injection, spray or internal ventilation inside containment, emergency control room and auxiliary shutdown panel.
    - steam relief to atmosphere
    - ultimate heat sink
    - safety compressed-air
    - emergency electrical power
    - resistance and integrity of various systems
    - safety systems instrumentation
    - primary system leak detection
    - detection of inadequate core cooling
    - seismic and environmental qualification of safety systems
- primary system integrity:
    - protection against cold and hot overpressure
    - protection against pressurised thermal shock
    - pressure vessel venting
    - integrity of primary pump seals
    - leak detection
    - boric-acid induced corrosion
    - list of actually incurred transients
- nuclear auxiliary building: protection against post-accident radiation
- inspection of structures and equipment (mechanical, electrical, civil works)
- test programme
- technical specifications
- operation organisation
- quality management
- spent fuel handling and storage
- gaseous effluent treatment and ventilation systems
- isolation and leak-tightness of primary and secondary containments
- hydrogen control inside containment
- operation experience feedback
- accident analysis review
- radiation protection and ALARA
- post-accident sampling in the reactor building
- updating of documentation, including amendment of the Safety Analysis Report.

5.B. Subjects examined during the First Safety Reviews of the Doel 3, 4 and Tihange 2, 3 Units, and Second Safety Review of Tihange 1

- conformity to the design bases: re-evaluation of the environment
- protection of electric safety circuits against lightning
- verification of extreme climatic conditions
- impact of the modifications made to the installations on the original "High Energy Line Break" (HELB) study
- loadings combinations on the structures
- anchorage of safety equipment
- use of the results of the qualification of mechanical equipment : components with a limited lifetime
- verification of the post-accident operability of pneumatic actuators
- dimensioning of miniflow lines of safety related centrifugal pumps
- post-TMI II.D.1 recommendation (mechanical resistance of the pressuriser discharge line)
- instability of the pressuriser safety valves during passage of the water plug
- qualification of the relief and block valves of the pressuriser
- taking into account secondary effects in the calculation of pipe supports in "Level D"
- thermal environment of electric equipment
- qualification of electric connectors: containment penetrations
- post-TMI II.F.2 recommendation (RM chains)
- follow-up of the US rules and practices
- general procedure for reloads safety justification
- follow-up of operational transients
- shift of the set point of the pressuriser safety valves
- pressure vessel embrittlement
- thermal ageing of stainless steel
- primary pumps: re-evaluation of the axial bearing
- risk of recirculation sump clogging during accidents
- containment spray water chemistry
- measurement of the containment free volume
- depressurisation of the safety injection accumulators
- availability of the LHSI pumps during recirculation
- manual initiation of the primary containment spray
- sub cooling measurement with core thermocouples to be qualified in the context of post-TMI II.F.2 recommendation
- verification of the response time of sensors
- protection of diesel groups in case of emergency signal
- availability of diesel groups during the sequence "SI signal followed by the complete loss of external electric grid"
- over speed protection of the emergency diesels
- availability of motors under degraded voltage conditions
- verification of the diesels loads
- loss of low voltage busses: procedures
- evaluation of the tightness of pool joints
- evaluation of the fire detection and protection
- ALARA policy
- post-TMI II.B.2 recommendation (post-accident accessibility)
- revision of the programme for the training and licensing of the personnel
- re-evaluation of the tightness tests of the recirculation lines
- functional tests of the shock-absorbers
- assessment of the periodic tests of pumps, valves and check-valves
- test console for logic and analogic protection signals
- global tests
- welding of the safe-ends on the pressure vessel nozzles
- pressure vessel inspection: underclad defects in the nozzles
- impact of the stainless steel cladding on the pressure vessel inspections with u.s.

- wear of the control rods
- corrosion of the reactor baffle screws
- corrosion of the guide tube pins
- follow-up of the internal structures of the pressure vessels by analysis of neutronic noise
- inspection of the steam generators: tube sheet — evacuation of the risk of under clad cracks
- welding of the partition plate on the water box on the tube sheet and the bottom of the steam generators
- steam generators: weld between the upper ring and the transition cone
- corrosion problems of valve bolts
- control of the pipe whip restraints
- internal corrosion of the SI accumulators
- post-earthquake procedure
- evolution of the ASME Code section XI
- ASME code section XI: appendices 7 and 8 (ultrasonic inspections)
- steam generator problems: limitation of the primary/secondary leak
- evaluation of the conclusions of generic studies of accidents not considered in the original design
- consideration of severe accidents
- probabilistic safety analysis
- re-evaluation of the Technical Specifications
- assessment of the implementation of the Q.A. programme
- software quality assurance
- quality management: Safety Evaluation Committee
- feedback of operating experience from Belgian and foreign plants
- assessment of incidents and synthesis of their causes
- evaluation of the modifications which can impact safety
- analysis of the influence of the emergency systems
- evaluation of voluntary inspections
- operator aids: shutdown mode
- operator aids during accidents
- primary breaks in modes 3 and 4
- thermal stratification in the pressuriser surge line
- thermal stratification in the main feedwater lines and their connection on the steam generator
- check valves: generic problems

5.C. Subjects examined during the Second Ten-yearly Safety Reviews of Doel l and 2

- ageing of electric equipment
- ageing of mechanical equipment
- ageing of the pressure vessel and of the primary circuit
- ageing of concrete structures
- ageing of the steam generators
- pressure vessel irradiation
- availability of the recirculation function
- antisiphoning system of the fuel pools
- seismic qualification
- qualification of safety related equipment
- qualification of high energy lines
- thermal stratification in the pressuriser surge line
- classification of safety-related equipment
- thermal stratification of feedwater lines
- qualification of the auxiliary feedwater system
- secondary overpressure
- loadings combinations in the reactor building cells
- implementation of ASME 1992
- re-evaluation of the Technical Specifications
- fire protection re-evaluation
- toxic gases protection reassessment
- improvement of the availability of the safety diesels
- dismantling
- ALARA
- software QA
- overlapping of tests for safety instrumentation
- quality assurance
- valving systems
- corrosion due to boron
- lightning protection
- operational transients
- protection of motors (under voltage)
- response time of radiological protection chains
- integrity of underground lines
- shielding of the radiological protection chains
- feedback of operating experience
- in service inspection
- procedures after earthquakes
- post-accident procedures
- severe accidents
- probabilistic safety analysis
- reassessment of accidents
- transport container for spent fuel assemblies
- set point statistical study
- re-evaluation of the environment
- inter-systems LOCA
- radiological consequences
- operational problems: follow-up of the pressure vessel internals

5.D. Subjects examined during the Second Safety Reviews of Doel 3 and Tihange 2, subjects to be examined during the Second Safety Reviews of Doel 4 and Tihange 3, and subjects to be examined during the Third Safety Reviews of Doel 1 & 2, and Tihange 1

- follow-up of US rules and practices
- definition of a source term for the reference accident
- post-'92 evolution of ASME XI Code OM
- re-evaluation of the conformity of the Single Failure Proof cranes with current standards
- re-evaluation of the Technical Specifications for the waste treatment building (WAB) at the Doel site
- re-evaluation of the Technical Specifications of Tihange 1
- re-evaluation of the Technical Specifications of Doel 1 & 2
- evolution of the environment and its impact
- re-evaluation of the impact of extreme climate conditions
- re-evaluation of the seismic level on the basis of recent investigations
- risk related to external flooding
- risk related to internal flooding
- systematic approach to assess the fire and explosion risk
- re-evaluation of ultimate heat sink (wells) at the Tihange site
- update of the PSA models
- safety analysis for shutdown modes
- follow-up of knowledge with respect to severe accidents
- analysis of the safety impact of flow dissymmetry between primary loops
- evaluation of main discrepancies with respect to the Position Paper on the application of the single failure criterion for the oldest units only :
- electrical support systems (Doel 1 & 2)
  - safety related systems (Doel 1 & 2)
  - heat sink (Tihange 1)
  - plant air (Tihange 1)
- updating accident procedures
- procedure for incidents during fuel handling
- procedure for loss of ultimate heat sink
- updating of incident procedures
- evaluation of PAMS measuring uncertainties
- availability of safety related components
- leak tightness of feedwater isolation valves
- follow-up of prestressing of the primary containment
- re-evaluation of the safety related ventilation
- reassessment of containment isolation
- pressurizing, of isolated piping in containment during accident conditions
- reassessment of ventilation for emergency building (Tihange 2)
- reassessment of ventilation for waste treatment building
- structural integrity reassessment of emergency buildings
- tests and criteria for safety related valves pumps, and diesels (Doel 1 & 2, and Tihange 1).
- evaluation of radiation exposure of plant operators during an accident
- isolation of normal feedwater (Tihange 1)
- optimization of containment spray lay-out (Tihange 1)
- containment spray additive (D12)
- application of ASME XI, Appendix OM to liquid discharging spring loaded safety valves
- verification of the efficiency of safety related heat exchangers
- follow-up of the pressure vessel embrittlement and protection against cold overpressure
- follow-up of ageing of guide tube split pins, of radial guides of the reactor vessel internals, of baffle bolts, of cast elbows, of safety related equipment, of temperature measurement probes in the primary loot by-pass, of CVCS heat exchangers and of elastomer supports
- follow-up of equipment fatigue (including thermal stratification)
- follow-up of corrosion phenomena in piping and line mounted equipment

- renovation of I/C systems and safety related components
- renovation of structures and buildings
- renovation of fire protection systems
- training of personnel and knowledge management
- design basis retrieval
- optimisation of ALARA policy
- qualification of software systems against smoke

5.E. Subjects examined during the Third Safety Reviews of Doel 3 and Tihange 2 and during the Fourth Safety Review of Doel 1 & 2 and Tihange 1

The third periodic safety reviews of the most recent units (Doel 3 and 4, Tihange 2 and 3), and the fourth periodic safety review of the Doel 1 & 2 and Tihange 1 units was executed according to the IAEA NS-G-2.10. This methodology is based on an assessment of 14 safety factors (SF) which are listed below, with respect to a reference framework of regulations and good practices. Both internal and external assessors, with the necessary qualifications in their field of expertise, were involved.

Subject area		Safety Factor
Plant	1	Plant Design
	2	Actual condition of systems, structures and components
	3	Equipment qualification
	4	Ageing
Safety analysis	5	Deterministic safety analysis
	6	Probabilistic safety analysis
	7	Hazard analysis
Performance and feedback of experience	8	Safety Performance
	9	Use of experience from other plants and research findings
	10	Organization and administration
Management	11	Procedures
	12	The human factor
	13	Emergency planning
Environment	14	Radiological impact on the environment
		Global assessment

During the various assessments, the assessors not only evaluated the results (e.g. performance indicators, physical condition of the installations), they also assessed underlying processes. The assessors had access to the entire installation, all procedures, all witnessing documents and experience reports. They interviewed the operational staff and the engineering company (Tractebel ENGIE). Per safety factor, the conclusions were registered in extensive reports that have been supplied to Bel V and the FANC. A global assessment of the plant’s strengths and opportunities for improvement was executed, which led to a plant improvement plan documented in the PSR synthesis report.

For some areas the PSR assessment of the Doel 1 & 2 and Tihange 1 unit differed from the more recent units, because of their LTO programme. Indeed design, actual condition of the SSC, qualification and ageing of SSC were even more thoroughly assessed for the oldest units.

The PSR action plan consists of the following main improvements which are valid for all units, and are being implemented:

- Extension of the methodology for monitoring the qualification of mechanical equipment.
- Execution of some specific safety studies such as the steam generator tube rupture.
- Re-evaluation and optimization of the performance indicators.
- Continuous follow-up of the impact of the expansion of the port of Antwerp for the Doel site.
- Check of the effectiveness of the actions resulting from the experience feedback and incident reports.
- Evaluation of the applicability of the newest standards for fire protection.
- Optimization of the radiological measurements and reporting.

For Doel 1 & 2 and Tihange 1 units, a specific LTO programme with important improvements regarding design and ageing of SSC is also ongoing to be completed before restart of the units in 2020.

Selection of important improvement actions from LTO action plan Tihange 1

Mechanical Systems and structures

Replacement of ISBP pumps	Done
Improvement of loose parts monitoring system	Done
Replacement of cooling groups	Done
Renovation of fire compartment barriers	Done
Renovation of cable trays	Done

Civil structures

Corrective actions identified after inspections	Done
Renovation of reactor building instrumentation	Done
Replacement of anchor cables roof nuclear auxiliary building	Done
Auxiliary feed water system building: soil consolidation actions after jet grouting incident	Remaining actions outage 2019

EI&C systems

Replacement of radioactivity measurement chains PIG (aerosols, iodine, gas)	Done
Renovation of alarm management system BETEA, renovation of communication systems	Done
Replacement of 6kV switchboard protections	Done
Replacement of safety related motors	Done
Replacement of AC and DC switchboards	Done

Replacement of rectifiers and ondulators	Done
Replacement of batteries	Done
Upgrade to conformity with qualification rules: electric penetrations reactor building, reactor protection system, pneumatic valves, transmitters	Done

Design

BEST – additional ultimate electricity supply	Done
BEST – reinforcement building electrical auxiliary building	Done
Filtered containment venting system	Done
Upgrade reliability residual heat removal system	Done
New full scope training simulator, including new "SUR-étendu" panels	Done
Upgrade instrumentation: new spent fuel pool level measurements, additional redundant steam generator and RWST level measurements	Done
"SUR-étendu" project: new auxiliary feedwater reservoir	Done
"SUR-étendu" project	Ongoing
Renovation and upgrade of fire detection and fire compartments	Ongoing

The « SUR-étendu » or « système d'ultime repli » is a project to reinforce the design of the existing ultimate emergency systems "SUR". These independent ultimate emergency systems are designed to able to bring the reactor to cold shutdown and cool the spent fuel pools in case of the unavailability of the main control room or even of the complete electrical auxiliary building "BAE", e.g. due to a fire. To do this the ultimate emergency systems are able to maintain the reactor subcritical, evacuate residual heat from reactor and spent fuel pools, control the primary system inventory and pressure. The improved ultimate emergency systems include an emergency control room, 2 redundant emergency diesel generators, 2 redundant RCP seal injection pumps with 7000ppm borated water source, an improved emergency steam generator feed water system (new redundant motor driven pump, new and larger water tank).

Selection of important improvement actions from LTO action plan Doel 1 & 2

Ageing mechanical

Optimisation maintenance programs active mechanical components (RCM of *Reliability Centered Maintenance*)	Done
Establish checklist for visual inspection of structures supporting systems in reactor building, annular space and nuclear auxiliary building	Done
Extension of inspection programs on pressure retaining bimetallic welds on reactor building penetrations.	Done

Ageing EI&C: Modifications and replacements

Qualified 380V and 6kV motor Scrambreakers Transmitters Fire detection consoles	Done
Reactor protection system (CPR) Process control systems (Teleperm, SIP) Reactor flux measurement chains (SIN) Control room alarms, buttons and systems Electrical supply systems (switchboards,…) Non-safety-related 380V switchboards	2018 – 2019 Doel 1: In preparation Doel 2: Done

Ageing civil structures: renovations

Concrete renovations river Scheldt water intake	Done
Renovation of nuclear auxiliary building stacks	2017 – 2019 In execution
Renovation exterior walls nuclear auxiliary building	2017 – 2019 In execution

Design-improvements

Improve fire detection reactor coolant pumps	Done
Improvement leak tightness main control room New toxic gas detection on main control room ventilation system Upgrade physical separation of electrical trains	Done
New submergible pumps to feed RW cooling towers with water from river Scheldt Automatic emergency feedwater supply to steam generator from GNS building Redundant emergency reactor coolant pump seal injection RJ pump Redundant (parallel) inlet valve for residual heat removal system	2018 – 2019 Doel 1: In preparation Doel 2: Done
New seismic fire water pump station with larger pumps and reservoirs Improving turbine hall automatic fire extinguishing system Improving fire compartments and automatic fire extinguishing in nuclear auxiliary and reactor building	2017 – 2019 In execution
Containment Filtered Venting System (CFVS)	2018 – 2019 In execution

Improvements related to BEST

Spent fuel pool water supply piping	Done
New mobile pumps and generators	Done

Improvements related to BEST

Improve seismic resistance RWST's + additional supply piping	Done

Appendix 6. Belgian Action Plan as a result of the European Stress test process

Table 12: External Events

Seismic resistance of SSCs	Tihange + Doel	As a result of qualified plant walkdowns (SQUG) and margin assessment (SMR), /improvement of the seismic resistance of several SSC
Re-evaluation of the seismic hazard		State-of-the-art probabilistic-seismic hazard re-evaluation (PSHA) of the site DBE & characterization of the site BDBE
Sensibilization campaign to seismic alertness		Continuation of efforts towards fostering awareness of potential seismic interaction inside facilities (scaffoldings,…)
Risk mitigation of internal flooding from circulation water circuit		Improvement of procedures after earthquake: quick local check of flooding (risk) and stop CW pumps accordingly
Secondary effect of earthquake Increase autonomy	Tihange 1	Assessment of earthquake impact on a fuel tank (fire, flood / resistance)

Enhanced protection Against flooding	Tihange	Acceleration of actions resulting from PSR study for new Design Basis Flood: Peripheral protection of the site Strengthening of NCM (robustness)
	Doel	Perimetric protection of relevant safety buildings (e.g. mobile barriers) Additional reinforcements of river embankments
Enhanced operation management (procedures)	Tihange	Accelerated implementation of emergency preparedness strategy, organisation and procedures about flooding
	Doel	Increase frequency of periodic inspections of embankments (height, erosion)
	Doel	Implementation of procedures for mobile barriers
Induced Internal hazards	Tihange	Internal hazards potentially induced by the flooding (fire, explosion) should be examined and additional measures should be taken where needed
Emergency	Tihange	For the flooding risk, further improvement of the emergency preparedness strategy

preparedness and response	and organization, including corresponding procedures, should be implemented
	Further robustness improvement of current emergency preparedness strategy for specific aspects (flooding alert system, communication, onsite transport, training, …)

Enhanced protection Against extreme Weather	Evaluation of protection against lightning (new standard NBN EN 62305)
	Reassessments of sewer system capacity should cover both short-duration heavy rains and long lasting rains for return periods far above 100 years. Depending on results, potential improvements of sewer system are to be identified. (still ongoing in 2019, for Tihange only)
	Tornadoes: confirm robustness of second-level systems of Doel 1 & 2 and Tihange 1 for beyond design tornadoes with wind speed exceeding 250 km/h (70 m/s)

Table 13: Design Issues

Loss of safety functions : Loss of Offsite Power

EDG autonomy	Tihange + Doel	Procedures to minimize the diesel consumption
		Procedure to anticipate the make-up of oil for the diesels
Offsite power Optimization	Tihange + Doel	Make a feasibility study to ensure a better separation of the high-voltage lines
		Agreement with grid manager for ensuring the prioritization of the external supply to NPPs

Loss of safety functions : Station Black-Out

Reactor building Confinement	Tihange + Doel	Assessment to verify whether all the containment penetrations can be closed in due time and whether the containment isolation systems remain functional
Operational procedures	Tihange + Doel	To define a global strategy in the case of a « total SBO »
Shutdown states & midloop operation	Tihange 3	Feasibility study to ensure make up for the primary system in case of primary system open

Instrumentation & Monitoring	Tihange + Doel	To add/check SFP level measurements
	Tihange	Diesel generators for resupplying the I&C
Specifications of NCM/ On-site resistant storage of NCM	Tihange + Doel	To justify the operability of the NCM on the basis of technical data (design, operation, alignment and connections, periodic testing, preventive maintenance, etc.)
		Account of the adverse conditions the NCM may be subject to (through technical characteristics and/or protection)
SG protection	Tihange + Doel	To assess the potential overfilling or drying-out of the SGs due to the loss of ultimate compressed air
AFW TP protection	Tihange + Doel	To assess the operability of the AFW turbine-driven pump due to the loss of ventilation in the turbine-driven pump room
Loss of safety functions : Loss of the primary and alternate UHS		
Operational procedures	Tihange + Doel	To define a global strategy in case of loss of all heat sinks (how to manage the overpressure in the containment)
Backup heat sink	Tihange	To integrate the use of the new groundwater of the site of Tihange in the supply of NCM equipment
Specifications of NCM	Tihange + Doel	To justify the operability of the NCM on the basis of technical data (design, operation, alignment and connections, periodic testing, preventive maintenance, etc.)

Table 14: Severe Accident Management and Recovery

Enhanced emergency management (PIU)	Tihange + Doel	Enhance the organisation and logistics of the internal emergency plan to include "multi-unit" events: description of the new organization implementation of the new organization
		Post-accident fixing of contamination and the treatment of potentially large volumes of contaminated water
	Tihange	New site operation centre ("COS") *(still ongoing in 2019)*
SAM mitigation - Design	Tihange + Doel	Filtered containment venting system on each unit – from preliminary study to installation

	Tihange	Feasibility study: additional water injection into the reactor pit + additional containment spray
H2 risk	Tihange + Doel	Assessment of the residual risk of hydrogen production and accumulation in spent fuel pool buildings
SAM – R&D	Tihange + Doel	Follow-up of R&D activities related to the corium-concrete interaction & steam explosion issues
SAM – Improvement Guidelines	Doel	Improvement of SAMG: decision support tools, long term monitoring and exit guidelines,…
SAM – Improvement Guidelines	Tihange + Doel	Improvement of SAMG: to include OEF Fukushima when WOG SAMG are revised
SAM – Training	Tihange + Doel	Increase consistency between Tihange and Doel NPP on SAMG training for operators
SAM – Control of releases	Tihange + Doel	Need to identify effective means to control pH inside containment
SAM – Power supply	Tihange + Doel	Optimal battery load shedding strategy + calculation and decision tool
Optimization of NCM	Tihange + Doel	Evaluation of the need to extend the NCM based on the analysis of the extensive damage mitigation guidelines ("EDMG")

FANC

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