KINGDOM OF BELGIUM

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

NATIONAL REPORT

August 2016

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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".

Table of Contents

I. Introduction

I.A. Content of the Present Report

This Belgian national report, submitted for the seventh 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 2014.

Section I.D gives an overview of specific actions related to the Vienna Declaration, as recommended during the preparatory meeting of the 7th CNS.

Section I.E lists planned actions to improve safety from 2016 onwards.

When drafting this report, due account was taken of the appropriate guidelines in INFCIRC/572/Rev.5 (5 February 2015).

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.

In order 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 found preferable to give in 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. Appendix 2 contains similar information about the BR1 and BR2 research reactors.

A list of the acronyms used in the present Report is given in Appendix 3.

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 (abbreviated as Electrabel),
- 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 a number of 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 in order to support the existing university laboratories and co-ordinate 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, a number of 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 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 an 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. This plant is now nearly totally 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" manufactures enriched uranium fuel assemblies, and was later on a part of the "Franco-Belge de Fabrication de Combustibles" (FBFC).

As regards the fuel cycle, the Mol Centre investigated several reprocessing techniques and, as a result of which the Eurochemic Consortium, formed under the aegis of the NEA (OECD), built its pilot reprocessing plant (adopting the PUREX process) in the Mol-Dessel region. This plant ceased its operations in 1975 and the main reprocessing building 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 fuel (Mixed Oxides fuel) batch for the French PWR power station Chooz A in 1986.

After having produced MOX fuel during 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. Activities in preparation of clearance of the buildings and of the site are currently underway.

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.

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

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 are or were present in Belgium. A full description of the nuclear sector in Belgium can be found in the book published by the Belgian Nuclear Society in 1995 "Un demi-siècle de nucléaire en Belgique" (i.e. Half a century of nuclear activities in Belgium: ISBN 90-5201-405-1) as well as in "Histoire du nucléaire en Belgique, 1990-2005" (Nuclear history in Belgium 1990-2005, ISBN 978-90-5201-377-0).

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 fifth review meeting of the Joint Convention, Vienna May 2015, available on the FANC and ONDRAF/NIRAS web sites.

Figure 1 : Nuclear sites in and near Belgium

The Doel and Tihange power plants are operated by Electrabel, a member of the ENGIE group that was created after the merger in 2008 of 2 groups "Gaz de France" and "Suez". In 2016, GDF Suez changed its name and became ENGIE. The share of ENGIE-Electrabel in electricity generating capacity in Belgium amounts to 65% in 2016. The tables below gives 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

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

This section focusses on new developments since 2014. This section also addresses issues raised during the Belgian presentation at the last review meeting, as reproduced in the table below:

Planned measures as reported during the 2014 review meeting	Ref.
Install new recirculation filters in Doel 3-4, and Tihange 2-3 by the end of '14.	I.C.3. d)
Finalize implementation of full level 2 Probabilistic Safety Analysis (PSA) for 4 representative units by '16, including low power and shutdown states	I.C.3. a)
Currently planning to conduct Reactor Pressure Vessel (RPV) inspections in Doel Unit 4 in '15. Doel Unit 1-2 will not be inspected because they will be shutting down in '15.	I.C.2. b)
Install filtered containment vents, a new emergency building, and a new simulator for Tihange Unit 1, in support of its life extension. Conduct periodic safety review (PSR) in Doel Units 1-2 to cover the period from the end of operation to the start of dismantling.	I.D.1, II.G.1.e) I.C.3 b)
Issue the new National Nuclear Emergency Plan by '14	II.C.5
Finalize management systems inspection activities to verify compliance with corrective action plan in '14.	II.H.6
Host SALTO mission in Tihange Unit 1 in 2015	I.C.1 a)
Electrabel to complete evaluation of safety electrical systems	I.C.3 e)
Address findings from the Integrated Regulatory Review Services (IRRS) mission and host a follow-up mission.	I.C.3 h)
Implement stress-test findings and recommendations	I.D.1
Implement the long term operation plan for Tihange Unit 1	I.C
Challenges as reported during the 2014 review meeting	
If nuclear power will be phased out, FANC and Bel V will need to increase the focus on decommissioning activities and the licensee will need to respond accordingly.	(I.C)
Finalize the implementation of the Fukushima lessons learned	I.D.1
Resolve flaw issues in the Doel Unit 3 and Tihange Unit 2 RPVs	I.C.2 a)
Implement the IRRS action plan	I.C.3 h)

Table 3: Planned measures and challenges as reported for Belgium at the 2014 review meeting

I.C.1. **Long Term Operation (LTO) of Tihange 1, Doel 1 and Doel 2 units**

a) SALTO mission in Tihange Unit 1 in 2015

In the framework of the long-term operation of Tihange 1, an IAEA peer review mission on safe long-term operation, SALTO, was requested for this unit. The first part of the review, the pre-SALTO mission, was conducted in 2012 to review programmes/activities that were launched or considered to prepare the unit for a LTO.

The second part of the review, the IAEA SALTO mission, was conducted in early 2015. The scope of this mission was the review of the status of the plant activities for a safe LTO, covering all areas : knowledge management, ageing management of structures, systems and components, internal organization,… One of the objectives of this mission was the follow-up of the recommendations and suggestions proposed during the pre-SALTO mission. The IAEA expert team concluded that the progresses are positive. Another objective was the review of the various LTO projects. IAEA experts thoroughly reviewed the licensees activities and issued 3 new recommendations and 7 suggestions to enhance the licensees activities. In addition the IAEA expert team highlighted a good practice concerning the sub-contractor management by the licensee.

The third part of the review, the follow-up SALTO mission, will be organized in December 2016 to evaluate the progress made by the licensee to answer the pre-SALTO and SALTO recommendations and suggestions.

b) The law of 31 January 2003 on nuclear phase out and the decisions on lifetime extension of the Tihange 1 (2012) and Doel 1 & 2 (2015)

According to article 4 of the law of 31 January 2003 on nuclear phase out, the lifetime of the Belgian NPPs was initially limited to 40 years. However, in order to ensure the electricity supply of Belgium, the government decided on the 4th of July 2012 to allow a lifetime extension of 10 year for the Tihange 1 NPP, which is consequently to be shut down in 2025.

In order to *ensure the energy supply in Belgium*, the government and the parliament reconsidered the definitive shut down of Doel 1 & 2 end 2014 and decided in 2015 to extend the lifetime of the Doel 1 & 2 units by 10 years, by amending art. 4 of the law of 31 January 2003 and thus fixing the date of shutdown of all Belgian reactors. As a result, the phase out law of 2003 has been modified for the second time, on June 28th, 2015.

The legal shutdown dates of the Belgian reactors are now:

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 4: Shutdown dates of the Belgian reactors

Note that the construction of new NPPs remains forbidden by this law (Article 3).

c) Long Term Operation of Tihange 1, Doel 1 & 2 : Action plan and license amendment

On the 4th of July 2012, the Belgian Government confirmed the shutdown of the Doel units 1 & 2 in 2015. From that moment the licensee started preparing a plan for the definitive shutdown of both units. The licensee revaluated - under the supervision of the safety authority - its action plans that had been set up in various contexts (Stress Tests actions, LTO-improvements intended to allow a possible long term operation, implementation of WENRA reference levels, …). As a principle, short-term actions were maintained and long-term actions were deleted. However, some of these long-term actions were partially maintained with a reduced scope, focusing on the equipment that will be required after definitive shutdown. Preparatory works and specific actions for a definitive shutdown were started, especially a project aiming at designing an on-site "waste management facility". The Periodic Safety Review, due 1st of April 2015, was completed with an adapted and specific scope, taking into account that the units had to enter a phase of "definitive shutdown".

Doel 1 was shut down in mid-February 2015 as planned.

Nevertheless, it was obvious by September 2014 that long-term operation for the units of Doel 1 & 2 was reconsidered as an option by the Belgian Government. The FANC developed conditions to prepare for this potential scenario. As a result, the licensee defined a new action plan, mainly based on the previous ones, in particular the 2012 LTO-action plan, with numerous design improvements and ageing inspections. Inspections of the reactor pressure vessels were also foreseen. A new schedule was set up, identifying priority actions that had to be carried out before the start of the first reactor cycle of the LTO-period and setting new deadlines (3 to 5 years) for non-priority actions or more significant design improvements. The action plan was submitted to the FANC in April 2015 for regulatory review. It has been analysed and approved in September 2015. In addition, a new PSR with a "long-term operation" scope was planned.

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 ionising radiation") to propose a license amendment for Doel 1 & 2 in 2015 in order to enforce this action plan. The license amendment also included particular requirements before the reactor could start its first LTO reactor cycle. The amendment to the license has been signed by the King on 27th of September 2015.

Doel 2 was shut down in autumn 2015 as planned.

Within the next few months the licensee implemented all the priority actions. In December, he submitted a progress report to the FANC. Considering this progress report and the results of various inspections and several meetings with the licensee, the FANC issued a positive opinion on the restart of the two oldest Belgian units. They resumed operation on 25 and 30 December 2015 respectively.

A similar LTO action plan was submitted in 2012 for the LTO operation of Tihange 1: some of the long-term actions are still to be completed. To enforce these long-term actions, the FANC decided in 2015 to make use of art. 13 of the GRR-2001 to propose to amend the license of Tihange 1 in a similar way as for Doel 1 & 2. The amendment to the license has also been signed by the King on 27th of September 2015.

d) Expert mission at Doel 1 & 2 units in 2016

Upon request of the Belgian Government at the IAEA, a peer review mission on safe long-term operation was conducted in February 2016 to review the programmes and activities of the Doel Nuclear Power Plant units 1 and 2.

This expert mission reviewed the status of the plant activities for a safe LTO. A preparatory meeting was held in August 2015. The scope of the expert mission covered the following areas of a SALTO peer review service : area A (Organization and functions, current licensing basis (CLB), configuration/ modification management), B (Scoping and screening and plant programmes relevant to LTO), D (Ageing management review, review of ageing management programmes and revalidation of time-limited ageing analyses for electrical and I&C components) and F (Human resources, competence and knowledge management for LTO).

Based upon the observations of this expert mission, the expert team reported good progress in the preparation for the long-term operation of the plant. The team has identified also some fundamental areas for further improvement. The majority of the issues are related to the interruption of LTO works between July 2012 and December 2015 due to the change in national nuclear strategy. Electrabel works on the identified improvement areas to solve these issues. A full SALTO mission is already planned in February 2017.

I.C.2. Reactor Vessel Flaws Issue

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 the licensee (Electrabel) could demonstrate to the FANC that the newly discovered flaw indications did not affect the safety of both reactors.

Electrabel's safety demonstration was recorded in two safety case reports, which were submitted to the FANC in December 2012. In January 2013, the FANC issued a provisional evaluation report that listed a number of short-term requirements, as well as several mid-term requirements. To meet these requirements, Electrabel established an action plan consisting of several additional analyses, tests and inspections.

In April 2013, the Licensee submitted two addenda to the safety case reports that provided a structured answer to each of the short-term requirements. An in-depth analysis of these documents by the Belgian regulatory body confirmed that all the safety concerns that were at the origin of the short-term requirements had been solved satisfactory. In May 2013, the FANC issued a final evaluation report and authorized Electrabel to restart Doel 3 and Tihange 2. Both reactors resumed electricity production in June 2013.

After the restart, Electrabel was expected to complete its mid-term action plan before the end of the planned outages of April and May 2014. However, partial and preliminary outcomes of two actions were unexpected and challenged the conclusions of the Licensee's safety demonstration. In February 2014, tests performed on the UT inspection device suggested that the flaw indications had not been accurately characterized. In March 2014 a test on the VB395 material (a material containing hydrogen flakes from a rejected Areva steam generator shell) showed that irradiation had a bigger impact on the embrittlement of that material than expected. As these outcomes raised questions about the extent and the understanding of the flaking phenomenon and hence also about the conservatisms of the safety cases, it was decided in March 2014 to advance the planned outages of both reactors and to immediately shut down the reactors.

Assisted by external experts, the licensee started an investigation of the impact of these unexpected outcomes on its safety demonstration and made an analysis whether or not the affected units could safely resume operation. The results of this analysis were recorded in two new 2015 safety case reports, which were supported by a number of technical documents.

As the scientific issues addressed in the safety demonstration required a highly specialized expertise, the FANC decided to seek the help of various experts groups, as they also did for the first safety cases. Each of these groups provided their own independent assessment of a specific part of the licensee's safety demonstration complementary to the assessments provided by Bel V and AIB-Vinçotte. An International Review Board consisting of renowned experts in the field of irradiation embrittlement evaluated the methodology proposed by the licensee to predict irradiation embrittlement of the flaked material. A National Scientific Expert Group, supported by additional experts, evaluated the hypothesis of hydrogen blistering or hydrogen induced cracking.

The US Oak Ridge National Laboratory (ORNL), was requested to provide fully independent advice. ORNL performed a complete evaluation of the material properties and structural integrity assessment to identify possible errors and to validate the results of the licensee Safety Cases. ORNL provided its own structural integrity calculations performed with codes and modelling tools which were different from those used by the Licensee. ORNL concluded that the structural integrity of Doel 3 and Tihange 2 is confirmed under all design transients with sufficient margin.

In November 2015 the FANC completed its safety assessment of the Doel 3 and Tihange 2 RPVs and came to its conclusion based on the licensee safety case reports - which were approved by the Licensee's Nuclear Safety Department - and the independent review and evaluation reports of Bel V, AIB-Vinçotte, the International Review Board, Oak Ridge National Laboratory, and the National Scientific Expert Group.

The FANC can confirm that all the safety concerns that were at the origin of the short-term and mid-term requirements have been solved in a satisfactory way. After a detailed evaluation of the potential impact of the unexpected outcomes from February and March 2014, the FANC has concluded that the new 2015 safety case reports provide an adequate demonstration of the structural integrity of the Doel 3 and Tihange 2 reactor pressure vessels up to 40 years of operation.

As a result, 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.

Some noteworthy conclusions of the evaluation are:

- The most likely origin of the flaw indications identified in the Doel 3 and Tihange 2 reactor pressure vessels is hydrogen flaking due to the manufacturing process.
- The application of a formally qualified UT inspection procedure during the 2014 follow-up UT inspections of the RPV core shells resulted in an updated flake cartography. The number of reported indications is significantly higher than in 2012, which is mainly due to the lowered detection thresholds and to the use of a more sensitive transducer. An update of the flaw sizing procedure resulted in an increase of the flake size to be taken into account in the structural integrity assessment.
- When applying the same parameters and reporting thresholds, a comparison of the data from the 2012 and 2014 UT inspections does not provide evidence for crack growth. A significant evolution of the size of the hydrogen flakes over time due to the stress of operation of the reactor units is deemed unlikely.
- The only theoretical propagation mechanism is low cycle fatigue, which is considered to have a limited effect. Other phenomena (such as hydrogen blistering or hydrogen induced cracking) have been evaluated and ruled out as possible mechanisms of in-service crack growth.
- Considering the VB395 to be an outlier for material behaviour under irradiation, the core shells of Doel 3 and Tihange 2 are unlikely to show the same sensitivity to irradiation embrittlement. Nevertheless, as a safety provision, the Doel 3 and Tihange 2 predictive equations take into account the atypical embrittlement observed in the VB395 flaked material. Therefore the FANC deems the predictive equations for irradiation embrittlement featured in the 2015 Licensee Safety Cases are acceptable.
- A conservative analysis shows that more than 99.75% of the flaw configurations in the Doel 3 and Tihange 2 RPV shells are harmless in normal or abnormal operating conditions. Based on a refined licensee analysis of the remaining 0.25%, the FANC

concludes that the safety margins are sufficient. These safety margins have been confirmed by the independent structural integrity calculations performed by ORNL.

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

The different reports have been published on the FANC web site: http://www.fanc.fgov.be/fr/page/1989.aspx?LG=1

b) Reactor Pressure Vessel (RPV) inspections at Doel 4, Doel 1,2 and Tihange 1, 3

Following the recommendation of the Western European Nuclear Regulators Association (WENRA) on the RPV issue, the FANC requested Electrabel to review the available documentation on the RPV manufacturing for all units and to perform complete Ultrasonic Testing (UT) investigations on all RPV core shells with the qualified procedure for the detection, location and sizing of hydrogen flaking indications. In addition the FANC requested to perform UT investigations of all forgings of all RPVs (core shells, nozzles…) and to conduct UT investigations of all forgings of the primary circuit of Doel 3 and Tihange 2 (steam generators, pressurizers…).

UT investigations were performed in Doel 1, 2 and 4 in 2015. No indications were detected. UT investigations of the RPV core shells were performed in Tihange 1 and Tihange 3 in 2013 with the 2013 UT procedure. No indications were detected. However, the FANC requested to perform new UT inspections on all forgings of the RPVs. This was done in 2015 for Tihange 3 and is planned in 2016 for Tihange 1.

I.C.3. **Other developments**

a) Development of PSA

Since the last report of 2013, an important effort was done on PSA Level 2: Level 2 PSA studies for internal events have been completed for the 4 representative units (Doel 1 & 2, Doel 3, Tihange 1 and Tihange 3) including for low power and shutdown states. Containment failure frequency, relative contributions of different containment failure modes and FP release frequencies (as a function of amplitude, timing and FP class) were some of the main results obtained. Some sensitivity studies have also been performed to better understand the behaviour of the plant and the relative importance of different severe accident management measures. The analysis of the results of the PSA Level 2 studies led to a list of recommendations for improvement which has been translated into an action plan. The majority of those actions concerned improvements to the severe accident management training programme i.e. to add emphasis to severe accident management actions having the highest impact on the mitigation of the releases. An evaluation of the applicability of this action plan to the other Belgian units (Doel 4 and Tihange 2) has also been performed.

Meanwhile, upgrades (including methodological improvements) of Level 1 and Level 2 PSA models taking into account a selection of recommendations coming from the peer review conducted by an external consultant in the framework of the Periodic Safety Review are ongoing for all units.

Updates of the plant data and configuration of Level 1 and Level 2 PSA models to take into account the plant status at the end of 2014 are also ongoing for all units.

The results of Level 1 and Level 2 PSA are used to identify weaknesses of the plant design and procedures. After each PSA project, a corrective action plan is defined by the utility in agreement with its architect engineer (which develops the PSA models).

First Level 1 Fire and Flooding PSA models for all units during power and shutdown states have been established in order to fulfil the requirements of the WENRA Reference Levels, which have been translated into the Belgian law under the Royal Decree of 30 November 2011. Level 2 Fire and Flooding PSA models have been elaborated for one representative unit.

The elaboration of Fire PSA models continues to refine the results (taking into account detailed circuit analysis, for example).

The utility uses more and more PSA as an additional tool to support safety decisions. It is for example foreseen in the utility procedures that PSA has to be used to assess plant modifications, procedures modifications and Technical Specifications modifications. It should be highlighted that PSA is nevertheless not a motive for changes in Technical Specifications.

b) *Periodic Safety Reviews 2012-2015*

The operators of nuclear power plant(s) are obliged under the Royal Decree of 31 November 2011 and the provisions of their license to conduct a periodic safety review every 10 years.

Since 2007 the FANC has required that plant operators perform this periodic safety review 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 successfully applied for the third PSR of the Doel 3 & Tihange 2 units, whose action plan is currently being implemented. For the other Belgian nuclear power plants, the evaluation phase has started end 2015 (3rd PSR for Doel 4, Tihange 3 and 4th PSR for Tihange 1). However, for the Tihange 1 reactor unit, the LTO evaluation process in 2012 already reviewed in detail several safety factors (safety factors regarding design and ageing). The consolidated action plan (T1, T3, D4) has been submitted in May 2016.

The same LTO evaluation process was completed in 2012 for Doel 1 & 2 (4th PSR). However, as the government decided to decommission the Doel 1 & 2 plant, the operator prepared a periodic safety review to anticipate the decommissioning of the plant. The report was sent to the regulatory body in April 2015. A change in governmental policy later made LTO operation of this plant possible and hence the operator has had to revise the PSR evaluation for this option. As for Tihange 1, several safety factors had already been reviewed in 2012. The review of the remaining safety factors was submitted at the end of 2015. Hence, the consolidated action plan (D1, D2) should be submitted before mid-2016.

When reviewing the new methodology for the periodic safety review process, it became obvious that the results and the defined actions focussed on procedural improvements rather than on an upgrade of the installation. It is however difficult to draw specific conclusions from this observation as major plant upgrades have already been considered in the framework of the European "Stress Tests" action plan and the LTO evaluations. Nonetheless, a more in-depth review of the methodology will be performed both by the regulatory body and the operator to assess its efficiency.

c) *Safety Culture Action Plan (2015)*

During the second quarter of 2015 several non-compliances with the technical specifications (Techspecs) were reported from 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 imposed in August 2015 enforcement measures. The FANC also asked the licensee to develop an action plan aiming at a drastic change in the safety culture of all employees at the Tihange NPP.

The licensee worked on a long term action plan called "Rigueur & Responsabilité". A first version was submitted to the FANC in January 2016. This plan has been updated in April 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 taking into account the feedback from Tihange and to define action plans in order to improve the safety culture as appropriate.

d) *Recirculation Filters*

As planned, new recirculation filters have been installed at the units Doel 1 & 2 and Tihange 1. The resolution strategy of the sump clogging issue for the units Doel 3, Doel 4, Tihange 2 and Tihange 3 has been modified in 2012. Reasons for this change were long-standing issues regarding the downstream effects, and more specifically the in-vessel effects and the lessons learned from the new filter test campaigns for the units Doel 1 & 2 and Tihange 1. Priority has been given to ensure a robust and test-based manner that potential recirculation filter clogging will not impede long-term recirculation. As a result, new filters are installed for these four units.

A study of the downstream effects is on-going.

To reinforce the recirculation function at Tihange 1, low pressure safety injection pumps have been replaced in April 2013.

e) Evaluation of safety of electrical systems

After the Forsmark-1 incident, the design of the safety electrical systems was further evaluated on the basis of the final recommendations of the CSNI Task Group related to Defence in Depth of Electrical Systems and Grid Interaction.

Different analyses investigated the possible transients that could occur taking into account the design of the Belgian nuclear power plants. Elements taken into account were the issues that could occur with rectifiers and inverters, motors, transformers and other electrical equipment due to lightning and voltage or frequency transients. Rectifiers and inverters appeared to be vulnerable components and have been replaced meanwhile. Furthermore, time delays in overvoltage protections have been modified to prevent Forsmark-like incidents.

During the replacements, adapted procedures were applicable and the operators were informed about potential failures induced by voltage transients. Simulations and tests performed with the full-scope simulators were used to train the operators. After replacements and modifications of the protection systems for the Uninterruptable Power Supply (UPS), the specific procedures were cancelled since no longer necessary.

The results of the extensive studies performed on voltage and frequency transients showed that those transients could not cause harm to the existing equipment. In addition, the analysis of the different issues highlighted in the WANO SOER 1999 and its addendum of 2004 showed furthermore that all Belgian units are able to resist Forsmark-like incidents.

f) Use of INES

INES (International Nuclear and Radiological Event Scale) has been used in Belgium for about 20 years now. In the early years, the scale was only used for the NPPs, but was rapidly extended to all major nuclear facilities, including nuclear research institutes as well as fuel cycle facilities.

The use of INES is implemented via a convention between the licensees, the FANC and Bel V. This convention 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 (http://www.fanc.fgov.be/fr/page/ines-un-outil-de-communication/221.aspx). 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.

In 2013, 2014 and 2015, the NPP Licensee reported respectively 10, 4 and 9 events classified as level 1 on INES . There was no incident classified as level 2 of higher on INES during the considered period.

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

g) Peer review missions

Peer reviews are regularly organized in Belgium. A list of recent or planned mission is given below:

- At the request of the Belgian Government, an OSART team from the International Atomic Energy Agency (IAEA) team visited the site of Tihange Nuclear Power Plant in May 2007, focusing on unit 1. The follow-up took place in February 2009.
- During the first three weeks of March 2010, an OSART-team from IAEA carried out an in-depth audit at units 1 and 2 of the Doel nuclear power plant. In March 2012, an IAEA team carried out a follow-up mission to the Doel NPP to examine how the operator has taken into account the recommendations and suggestions made in the 2010 OSART mission.
- According to the European Directive 2009/71/Euratom, self-assessments and peer reviews missions are mandatory every 10 years in European Member states. The Belgian Regulatory Body performed a self-assessment between June 2011 and September 2012. An IRRS mission itself took place in December 2013.
- In the frame of the decision for life extension (LTO) of Tihange 1, the FANC requested the IAEA to perform a SALTO (Safety Aspects of Long Term Operation) for this reactor. This mission took place from 13 to 22 January 2015. The final report is available on the

FANC web site : http://www.fanc.fgov.be/GED/00000000/3900/3948.pdf. The follow-up mission is foreseen in December 2016.

- In November 2014, Belgium hosted an IAEA IPPAS (International Physical Protection Advisory Service) mission.
- An expert (reduced SALTO) IAEA mission was organized at the Doel 1 & 2 NPPs from 1 to 9 February 2016. The full SALTO mission itself will take place in 2017.

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

h) IRRS mission to Belgium in 2013 : Action Plan and Follow-Up Mission

The Belgian Regulatory Body received an IRRS 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 (http://www.fanc.fgov.be/GED/00000000/3500/3594.pdf).

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 addresses the recommendations and suggestions, but includes 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 resulting action plan is composed of 3 main "programmes" :

- Management System: mainly deals with the internal organisation and has as objective to develop and implement a management system such as described in IAEA GSR Part 2. Part of the management system already was available as part of the ISO 9001 quality management system. Some aspects were not covered and specific actions are planned/performed, in particular related to
  - Safety & Security culture within the regulatory body
  - Systematic application of graded approach
  - Development of specific policies and processes related to all regulatory activities
  - Resource management
- Future of the Regulatory Body: deals with specific strategic options to be chosen within a short to medium time frame. Typical topics include
  - National policy on nuclear safety
  - Consequences of the nuclear phase out in Belgium (financial, waste management, type of activities, …)
  - Interactions with other institutions performing regulatory activities
  - Review of regulatory framework
- Specific Actions : this programme covers all subjects that have been identified by the IRRS-mission and the strategic plan methodology as individual actions or projects that are not necessarily to be performed within the two other programmes. Typical examples of such actions include
  - Development of dosimetric passport
  - Development/revision of specific regulation regarding security, transport, European BSS,…
  - Development of additional guidance with respect to decommissioning, emergency planning and preparedness, …

The FANC and Bel V intend to receive the IRRS follow-up mission in the second half of 2017. The first steps for this follow-up mission have already been taken.

i) R&D Programme in safety

The Belgian **Regulatory Body** (FANC and Bel V) is active in many R&D activities; FANC mainly in the area of radiation protection, Bel V mainly in the area of nuclear safety.

Since the last report of 2013, the main efforts in the area of R&D for nuclear safety are given hereafter:

Thermal hydraulic accident analysis: Bel V runs since a long time the CATHARE code (co-owned by CEA, EDF, AREVA-NP and IRSN) and obtained more recently also the RELAP-code. The latter is being used as well to perform accident analyses for NPP, as for exploring the possibilities to model a lead-bismuth cooled research reactor.

Bel V also continues its important effort to participate in projects managed by NEA (OECD) such as PKL and ATLAS.

Severe Accidents Progression : Bel V joined the CSARP programme managed by USNRC and holds the CSARP agreement with USNRC for Belgium. In this context Bel V obtained the MELCOR code and started to work with the code by developing MELCOR input decks for the Belgian NPP.

In support of Bel V's activities related to the filtered containment venting system analysis, in the framework of the "Belgian Stress Tests" (BEST) action plan, Bel V continued its participation to meetings of the OECD WGAMA (Working Group on Analysis and Management of Accidents) Task Group on Filtered Containment Venting.

In support of Bel V's activities related to fission products and aerosols behaviour in severe accident conditions, Bel V continues its participation in the BIP-projects managed by NEA (OECD), by joining the new phase BIP-3 (to be started in 2016).

Seismic Hazard Assessment: Earthquakes are important threats to nuclear installations and should therefore be thoroughly considered during the lifetime of such installations. In this frame, knowledge has to be updated with new data and take into account new technical developments. A new reassessment was conducted in cooperation with the FANC, based on data provided by the Royal Observatory of Belgium (ROB). Reassessment with a deterministic approach will be conducted by Bel V. An updated probabilistic approach was conducted by the ROB.

Fire protection: Bel V continues its participation in the PRISME project series of NEA (OECD).

Waste management: Bel V has made a considerable investment in obtaining expertise in independent modelling of waste management issues, for instance by modelling issues using the HYTEC and FEFLOW computer codes.

Bel V also actively participates in R&D projects sponsored by the European Commission via Framework programmes or Horizon2020. For instance, Bel V is presently participating in the Sustainable network for Independent Technical Expertise of radioactive waste disposal (SITEX) and Joint Programming on Radioactive Waste Disposal (JOPRAD).

Sponsoring R&D: in the last few years, Bel V increased considerably its effort to sponsor nuclear safety related research with Universities and R&D institutes. These efforts are mainly undertaken by sponsoring doctoral thesis projects or post-Doc positions. The main areas in which projects are sponsored are fire protection, thermal hydraulic analysis and waste management issues.

Electrabel is also active in the field of R&D, in collaboration with other division of the ENGIE Group. The Group has defined its R&D needs up to 2020, 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.

With regard to Plant Safety, activities , amongst others, that were followed up or are upcoming are

- Phenomena occurring during transient, incident conditions and accident conditions:
  - Participation in NEA (OECD) WGMA projects (e.g. ROSA, PKL, BEMUSE)
  - Participation in NEA (OECD) 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 via Nugenia
  - Participation in SARNET and 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 ACE/MACE, MCCI, CCI and VULCANO (corium concrete interaction and ex-vessel coolability)
- Air-SFP (spent fuel pool air-ingress scenarios) with MELCOR
- IVMR (in vessel melt retention) with MELCOR

With regard to LTO, current activities in ageing are, amongst others participation to research programs with SCK•CEN and CEA in the fields of RPV embrittlement, IASCC, PWSCC of Inconel and cable ageing, and participation to EPRI Steam Generator Program Management and Water chemistry program.

This list is non-exhaustive. The R&D roadmap is being revised on a periodic basis.

I.D. Actions in relation with the Vienna Declaration

Belgium is making efforts for the implementation of the Vienna Declaration through:

- The "Stress Tests" process and the resulting safety improvements
- The adoption of the new European Directive 2014/87/EURATOM, which namely imposes topical peer reviews
- The new regulatory project to include the WENRA reference levels into the Belgian legal framework
- The development of several guidance by the FANC giving reference values for the safety objectives

I.D.1. Completion of the "Stress Tests" Action plan

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 : http://www.fanc.fgov.be/fr/page/stress-tests-nucleaires/1411.aspx (in Dutch and French).

As result of the Stress Tests, the ENSREG action plan and the peer review and findings of the extraordinary meeting of the CNS in 2012, a Belgian national action plan was issued in December 2012. More than 300 individual actions have been identified.

This Belgian National action Plan (NAcP) is available on the ENSREG web page: http://www.ensreg.eu/node/694 (in English).

The Belgian National action plan is closely followed-up by the Regulatory Body. In this respect, the FANC publishes an annual progress report on the Belgian Stress Tests action plan on its website. **Appendix 6** gives an overview of this action plan, mentioning the issue, the site(s) concerned, the action type and the target implementation date.

The final national reports have been reviewed by Review Teams, set up by ENSREG. The peer review process is now finished. ENSREG has endorsed the ENSREG Summary Report (http://www.ensreg.eu/EU-Stress-Tests/EU-level-Reports) on 26 April 2012 with the 17 country specific peer review reports attached to it

By 31 December 2014, each European country was requested to update its original NAcP to reflect developments since its issue and the current status of the measures and their implementation. The updated NAcPs have been published on the ENSREG website and a 2nd ENSREG Post-Fukushima National Action Plans Workshop took place 20-24 April 2015, in order to discuss and review the implementation level of the actions plans.

In 2015, the main achievements and progresses of the Belgian action plan to note are:

- The protection against beyond design flooding is now fully operational on both sites.

- The strategy for the Complete Station Black-Out is now well-defined on both sites. The induced actions as well as the actions concerning the loss of the Ultimate Heat Sink, are ongoing at Tihange and effective at Doel.
- A new strategy for the emergency response centre in Tihange (COS) has been proposed and is now under review by the regulatory body.
- The design of the filtered venting systems is completed and the realization phase has been started. The filtered vents should be operational in 2017 with the exception of Doel 1 & 2 units for which the foreseen installation date is 2019.

The regulatory body considers that the progress made in 2015 is satisfactory but notes delays in the implementation of the Stress Tests action plan. Most remaining actions are now beyond the time schedule of the original action plan by on average more than one year. These delays have been duly justified by the licensee for technical or procurement difficulties. They are also partly due to changes in the action plan due to the review of the feasibility and preliminary studies by the regulatory body. On both sides the workload of the Stress Tests project has probably been underestimated when setting the deadlines.

By March 2016, 82% of the actions stemming from the action plan are closed (300 actions out of 366). Among these:

- 149 actions are closed with Bel V confirmation;
- 84 actions are closed with questions from Bel V to answer;
- 67 actions are closed without confirmation or question from Bel V.

The regulatory body will continue to carefully monitor the progress of the stress test actions implemented by the licensee in the future years.

The current status of the Belgian National Action plan is available on the FANC web site (in English) : http://www.fanc.fgov.be/GED/00000000/4000/4093.pdf (March 2016 edition).

I.D.2. **The revision of the European Directive on Nuclear Safety (2014/87/Euratom)**

On the basis of nuclear Stress Tests carried out from 2011, the lessons learned from the Fukushima nuclear accident and the safety requirements of the WENRA and the International Atomic Energy Agency, the European Union amended its first Nuclear Safety Directive (2009/71/Euratom) in 2014.

The amended Directive requires European countries to give highest priority to nuclear safety at all stages of the lifecycle of a nuclear power plant. Specifically, the Directive:

- strengthens the role of national regulatory authorities by ensuring their independence. EU member states must provide the regulators with sufficient legal powers, staff, and financial resources
- creates a system of **topical peer reviews**. European countries choose a common nuclear safety topic every six years and organise a national safety assessment on it. They then submit their assessment to other countries for review. The first topical peer review organized by ENSREG on "**ageing management**" will start in 2017, on the basis of technical specifications prepared by the WENRA.
- requires a periodic safety review of all nuclear power plants to be conducted at least once every 10 years
- increases transparency by requiring operators of nuclear power plants to release information to the public, both in normal operation and in case of incidents.

Article 8.a of the 2014/87/Euratom Directive sets out the objectives of the Vienna Declaration :

Nuclear safety objective for nuclear installations

1.Member States shall ensure that the national nuclear safety framework requires that nuclear installations are designed, sited, constructed, commissioned, operated and decommissioned with the objective of preventing accidents and, should an accident occur, mitigating its consequences and avoiding:

(a) early radioactive releases that would require off-site emergency measures but with insufficient time to implement them;

(b) large radioactive releases that would require protective measures that could not be limited in area or time.

…

This objective …. is used as a reference for the timely implementation of reasonably practicable safety improvements to existing nuclear installations, including in the framework of the periodic safety reviews

Many provisions of this Directive are already present in the Belgian legal framework (e.g. PSR to be performed every 10 years). To be compliant, this directive will be fully implemented in the Belgian regulations by mid-2017.

I.D.3. **WENRA revised set of Safety Reference Levels of September 2014**

As a result of the Fukushima-Daichi accident, theWestern European Nuclear Regulators Association **WENRA** was tasked to review the reference levels for existing reactors. The Reactor Harmonization Working Group (RHWG) issued in September 2014, a revised set of reference levels. This revised set of reference levels put more emphasis a. o. on :

- Safety Culture
- Accidents affecting multiple installations on a site
- Long lasting events (staffing & autonomy)
- Fuel in the spent fuel storage
- Emergency Operating Procedures and Severe Accident Management Guidelines (including the use of mobile means)
- Design extension conditions
- Natural Hazards, including considerations for large-scale destruction of infrastructure in the vicinity of a site

The revised set of the WENRA reference levels contains a provision in line with the Vienna Declaration: The safety reference level F4.14 of the safety issue "F- design extension-" states :

In DEC A (accidents without core damage) , radioactive releases shall be minimised as far as reasonably practicable.

In DEC B (accidents with core damage), any radioactive release into the environment shall be limited in time and magnitude as far as reasonably practicable to:

(a) allow sufficient time for protective actions (if any) in the vicinity of the plant; and

(b) avoid contamination of large areas in the long term.

The FANC started in 2015 a new regulatory project in order to translate the new WENRA safety reference levels into the Belgian regulations. The regulatory project will amend the existing royal decree on the safety of nuclear installations (30/11/2011) and is expected to be issued end 2017.

FANC and Bel V also started a gap analysis, checking the implementation of the WENRA Reference Levels 2014 in the NPPs. This gap analysis is presently being discussed with the licensee, that has also anticipated this upcoming regulatory change and has carried out a gap analysis.

I.D.4. **Technical criteria for the safety objectives of the directive 2014/87**

The Belgian regulatory body has developed guidelines on safety demonstration and specific external hazards for new nuclear installations (except waste disposal facilities). The guidelines on safety demonstration outlines the expectations of the nuclear regulator with respect to defense in depth, quantified safety objectives and external hazards in general. The specific guidelines on external hazards provide expectations on how one or more hazard levels can be derived with the purpose to include these levels in the safety demonstration; these guidelines address respectively seismic hazards, unintentional aircraft crashes and external flooding. The guidelines have been developed using several sources including IAEA standards, WENRA positions and the recently issued European Council Directive 2014/87/Euratom of 8 July 2014 which amends Council Directive 2009/71/Euratom. The content of the guidelines have also been discussed extensively with licensees and advisory bodies.

The table below gathers the of off-site radiological "Safety Objectives" for the different design basis categories:

Design Basis Categories	Radiological Safety Objective:
C1 "Normal operation"	See article 20.1.4 of the GRR-2001
C2 "Anticipated operational Occurrences"	For events at least as frequent as once in a year: • Effective dose/event < 0,1 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 0,3 mSv/event; For events less frequent than once in a year: • Effective dose/event < 0,5 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 1,5 mSv/event; considering the whole time period of the releases or the duration of direct irradiation exposure. The effective dose should take into account direct exposure, cloud shine, and inhalation. The thyroid dose should be calculated taking into account inhalation only.
C3a "Postulated single initiating events" C3b "Postulated multiple failure events"	• Effective dose/event < 5 mSv/event; • Equivalent thyroid dose/event for the infant, child or adolescent < 10 mSv/event; considering the whole time period of the releases or the duration of direct irradiation exposure. The effective dose should take into account direct exposure, cloud shine, and inhalation. The thyroid dose should be calculated taking into account inhalation only. • Lifetime effective dose/event < 1 Sv /event, beyond the site limits (all paths); • Agricultural products should be consumable one year after the accident, beyond the site limits.
C4a "Severe Accidents not practically eliminated"	• Effective dose/event < 50 mSv/event beyond the evacuation zone. The dose should be integrated over 7 days; • Effective dose/event < 5 mSv/event, beyond the sheltering zone. The dose should be integrated over 24 hours; • Equivalent thyroid dose/event for the infant, child or adolescent < 10 mSv/event during cloud passage, beyond the sheltering zone; considering the whole released source term. The effective dose should take into account direct exposure, inhalation, cloud shine and ground shine. The thyroid dose should be calculated taking into account inhalation only. • Lifetime effective dose/event < 1 Sv /event, beyond the site limits (all paths); • Agricultural products should be consumable one year after the accident, beyond the sheltering zone.
C4b "Severe Accidents practically eliminated"	Not Applicable

Table 5: Summary of off-site radiological safety objectives

These guidelines have been published on the WENRA web site : http://www.wenra.org/archives/fanc-publishes-guidance-notes-new-nuclear-class-i-/

I.E. Planned measures to improve safety

In summary, for the **regulatory body**, the following measures to improve safety are planned for the next review period 2016-2019 :

a) Legal framework improvement :

- The incorporation into Belgian regulations of the WENRA 2014 Safety reference Levels and of the European Directive 2014/87/EURATOM
- The incorporation into Belgian regulations of the European Basic Safety Standards (Directive 2013/59/EURATOM)
- The completion of the new national Nuclear Emergency Plan

b) Oversight of the timely implementation and the completion of the different actions plans of the licensee:

- The "Rigueur et Responsabilité" action plan
- The action plan resulting from the new Fire Hazard Analysis
- The Stress-tests action plan (BEST)
- The LTO action plan for the concerned units
- The action plan that will result from the benchmarking with the WENRA 2014 Safety Reference Levels

c) The completion of the 2013 IRRS action plan and the IRRS follow up mission planned end 2017

d) The participation in the European Topical Peer Review organized in 2017-2018

e) Continuation of international activities and cooperation

For the **operator**, significant actions to improve safety are planned for the next review period 2016-2019 :

a) Installation of reactor pit injection means and alternative sprays at the Tihange Plants (in the framework of BEST)
b) Alternative seismically robust electrical power supply at Tihange (in the framework of BEST)
c) Installation of filtered vents by 2017 on Tihange 2 and 3, and Doel 3 and 4 (in the framework of BEST)
d) Installation of filtered vents in Tihange 1 and Doel 1 & 2 by 2017 and 2019 respectively (in the framework of LTO)
e) Commissioning of the SUR-Etendu in 2019 (in the framework of LTO Tihange 1)
f) Reinforcement of the fire protection at Tihange 1 by 2019 (in the framework of LTO)
g) Reinforcement of the Ultimate systems of the GNS (in the framework of LTO Doel 1 & 2)

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 and the promulgation of the royal decree with 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 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), available on the FANC web site.

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 license of the facilities and now by the Royal Decree of 30 November 2011 (SRNI-2011). The current status of the PSRs is described in section I.C of the present report.

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. A table with a more complete overview of important projects (besides the PSR) is given below:

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 6 : 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 results from the WENRA RHWG self-assessments and benchmarking project, for which the results were published early 2006 (see WENRA website). This action plan covers 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 the licensee and reviewed by the Federal Agency for Nuclear Control (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, FANC published conditions, to which the operator 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: priority 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 have to be executed before the restart and other actions that the licensee has to finish before 2019 (e.g. the installation of the FCVS system; seismic upgrade of the RWST's, new seismic fire pump station, …). Doel 1&2 restarted end of December 2015. The execution of the other actions is going on.

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, the licensee was asked to conduct Stress Tests. Safety assessment reports for the Doel and Tihange sites have been established by the licensee 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 are 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.

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 during the next decade.

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 appendix 2.

Following the Fukushima Daiichi accident, SCK•CEN was asked to conduct Stress Tests as well as other nuclear installations. 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. Some major investment projects are still going on.

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 1965 the BR1 is operated 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 replacement is foreseen at this moment. In 1963, after a long period of operation at high 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 / (cm².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. This still is an important activity. A number of irradiation devices are available. However during the last years isotope production (Mo-99, Ir-192 and others) have become an important activity. Besides this, 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 should restart 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. Major works include the replacement of all underground piping, improvement of the electricity and instrumentation cabling by installing additional separate cable routes and the upgrade of hoisting devices by making them single failure proof. For a number of components and systems, design upgrades are made, to improve the safety and reliability. In the framework of the Stress Tests, a monitoring system is foreseen 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 consented to 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 are foreseen in the BR2 reactor in the period 2016 – 2023.

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 evaluated in order to be able to adopt an evolutionary higher density version of the U_3Si_2 based LEU fuel system, which in lower density is already qualified for medium power research reactors.

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 basic Belgian legal texts regarding 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 2012),
- 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 2015),
- The Royal Decree of 30 November 2011 on the Safety Requirements for Nuclear Installations (SRNI-2011 amended for the last time in 2015).

Besides these, other legal texts relate to some aspects covered within 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 reinforcing considerably 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 enforces 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 this public agency is explained under Article 8. This agency, which is endowed with wide competences, **constitutes the Safety Authority.**

The texts of the regulations now in force can be consulted on the website of the FANC (http://www.jurion.fanc.fgov.be). An English version of some of these texts is available on the FANC website: http://www.fanc.fgov.be/fr/page/reglementation/11.aspx.

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 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 are considered as judiciary police officers, auxiliaries of the King's Attorney and, as such, they have specific enforcement powers. They trace and record infractions to this law; they can issue warnings and set deadlines for corrective actions; they have at any time access to the nuclear installations; 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 license applications for nuclear facilities; to grant licenses for specific facilities, except those with the highest risk (class I facilities); the verification of compliance with license 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; the stimulating and coordination of R&D;
  - to issue neutral and objective information to the public.
- **Chapter IV** deals with the delegation of some of the missions of the FANC.
  - the FANC can delegate some of its missions to organisations that it has recognized or to legal entities that it has created to that end;
  - the delegation relates to certain missions of the health physics department that each licensee has to set up as well as the supervision of loading, transport and delivery of fissile material;
  - the recognition of those organisations is based on criteria defined by the FANC;
  - the missions delegated to the legal entities that the FANC created, are specified by the King who also determines the way of financing the entity as well as how the FANC can control the mission entrusted to this entity.
- **Chapter V** deals with the funding of the FANC, which is based on
  - annual taxes on license holders or future license holders (e.g. the projects for disposal of radioactive waste); the amounts and the procedure for paying are fixed in this chapter;
  - fees on the occasion of the application for a license, 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 enforcement powers that the FANC can use 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 Safety Authority 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 are 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 and is described at the end of this section.
  - Art. 12 and 13 deal with the licensing issues due to modifications to the facility or the additional license conditions that can be proposed by the FANC or its scientific council.
  - Dismantling of Class I facilities is also subject to prior licensing.
  - The competent authority may withdraw or suspend the license when the regulations and/or license conditions are not complied with
- **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 license holder of a facility or operator of a transport company must establish. The HPD is in charge of the organization and supervision of the measures to ensure compliance with the regulations and with the conditions set in the licence. Specific tasks of the HPD are listed in Art. 23. Experts in health physics control must be recognised by the FANC according to specifications 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** - Import, Transit and Distribution of Radioactive Substances
    - This chapter has been withdrawn and replaced by the Royal Decree of 24 March 2009 regulating import, transit and export of radioactive material. This decree also transposes Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel.
- **Chapters V and VI** deal with medical applications of ionising radiation and are not reported under this convention.
- **Chapter VII** – Transport
    - Transport of radioactive material is subject to a licence granted by the FANC.
    - This chapter describes the licensing procedure as well as the information that the licensee has to provide to FANC on a regular basis.
- **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 licenses 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 the 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 17 October 2003 has laid down the general Emergency planning organisation in case of nuclear/radiological accident (see also II.C.5).
- **Chapter XII** - **Recognition of Experts**, Physicians and of Inspection Organisations
    - Article 73 sets all the conditions for the recognition of experts in health physics control.
    - Article 74 deals with the Authorized Inspections Organizations (AIOs).
    - 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 this decree.
  - Section I – Nuclear Safety Management
    - 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. 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.
    - Art. 6 sets out the requirements with respect to training and formal qualification of the personnel.
  - Section II – Design
    - 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 some 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. This 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 method and shall address various safety topics. 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.
    - 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 already into account the main elements of the fire protection and has to be documented via a fire hazard analysis. The 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 the 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 reach. It also request 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 demanding 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 beyond design accident, the containment must be maintained as much as possible.
    - Art. 22 states that interfaces shall be present to prevent that a failure of 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). 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 sensitivity analysis. The PSA results shall be used during the design and operation of the power plant for e.g. decision making aid or to check adequacy of modifications.
    - Art. 30 sets the frequency of the periodic safety reviews at a minimum of 10 years.
- 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 requirement 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** is intended to set specific safety requirements for radioactive waste disposal facilities.
- **Chapter 5** contains some final provisions and transitional arrangements

II.C.5. **The Royal Decree of 17 October 2003 on Emergency Planning**

The law of 15 May 2007 defines the notion of Civil Safety and describes the roles and missions of the different entities involved. The Royal Decree of 16 February 2006 organises the planning and interventions during emergency situations. The Royal Decree of 17 October 2003 lays down the nuclear and radiological emergency response plan and the tasks of each of the parties involved.

According to article 18 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 Safety.

This nuclear and radiological emergency plan for the Belgian territory aims at co-ordinating the actions towards protection of the population and the environment in the event of a nuclear accident or any other radiological emergency situation that could lead to an overexposure of the population 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 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 fuel fabrication factory Belgonucléaire (now in dismantling phase) and the waste treatment and storage installations of Belgoprocess in Dessel. This plan is also activated for other emergency situations, which can occur either on the Belgian territory (accident during the transport of radioactive materials or radiological emergency resulting from a terrorist attack or events occurring in other Belgian nuclear installations for instance) or nearby (EdF nuclear power plant of Chooz for instance).

In case of an emergency, the off-site operations are directed by the "Governmental Crisis and Coordination Centre" (CGCCR), 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.

It is worthwhile noting that this plan is presently under revision to cope with the lessons learned from the Fukushima accident, exercises, the revision of international standards and most recent international recommendations and the changes in the structure and responsibilities of the Belgian federal and regional authorities. The new version is expected by 2017.

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 lifetime 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.

The legal shutdown dates of the Belgian reactors are (Article 4):

Doel 1	15 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

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

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 license 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 85/337/EEC on the assessment of the effects of certain public and private projects on the environment (as amended).

Belgium is a federal state composed of three Regions being legally competent for environmental protection on their territory (radiological impact excluded). Future cooperation agreements are being discussed in order to avoid work duplications and incompatibilities and to streamline the licensing procedures

The licence application is examined by the FANC and 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 municipal authorities concerned for advice, and then to the executive of the provinces concerned. 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 license, 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 allows the applicant to build the installations in conformity with the licence.

The second phase aims at confirmation of the construction and operation licence. The Federal Agency for Nuclear Control (FANC) or Bel V acting on behalf of the FANC proceeds to the delivery of the installations before the start up and the introduction of radioactive substances. A fully favourable acceptance report leads to the confirmation decree allowing the operation of the facility.

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

The licensing scheme is illustrated in the figure below.

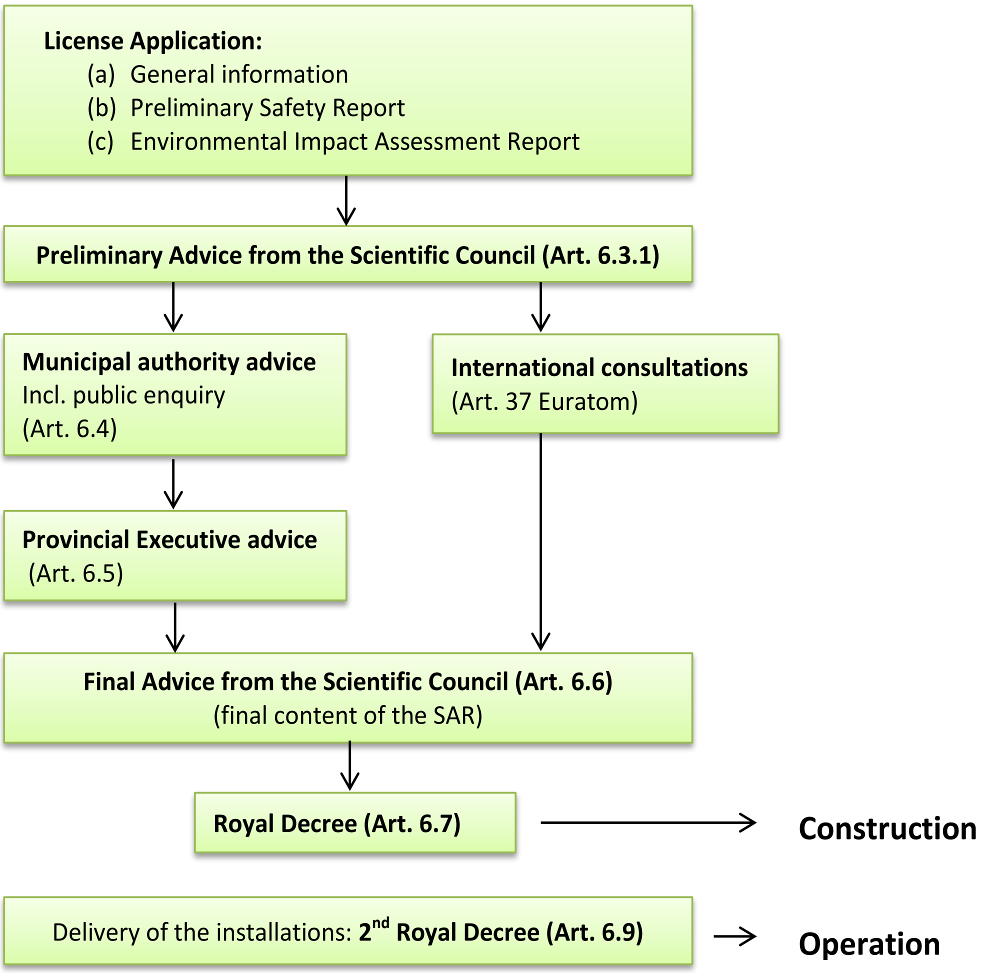

Figure 2 : Licensing scheme for Class I Facilities

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 cancellation of the decree, during 60 days after the publication of the decree.

The administration in charge of treating the appeal against the administrative decision 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 immediately the administrative decision.

Modification of the license:

The licence and the conditions attached to the license 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 license 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 license 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 in II.C. 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),

(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).

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 within the responsibility of the Federal Agency for Nuclear Control (FANC), which constitutes the Safety Authority. This mission has been given to the FANC by the Law of 15 April 1994. According to articles 14bis and 28 of this law (as amended), the FANC may call upon the assistance of recognised bodies for health physics control, or on legal entities especially created to assist it in the execution of its missions. The FANC has made use of this provision and, in the case of the nuclear installations covered by this National Report (nuclear power plants), created Bel V in September 2007, a subsidiary with the statute of a so-called 'foundation' as defined in Belgian law. Bel V is given a mandate to perform regulatory missions that can be legally delegated by the FANC, without consulting the public market. The FANC delegates different tasks to Bel V, a.o. on site routine inspections. Other class I facilities (including the Research Reactors) are controlled in a similar way 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.

The staff of Bel V is composed of experts from the former recognized body (Authorized Inspection Organisation) AVN and is carrying out all the regulatory activities since April 2008, including the surveillance activities, previously performed by AVN. Background elements regarding AVN and the statute of "Authorized Inspection Organisation" can be found in the 2007 edition of this national report, available on the FANC web site.

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 regulatory tasks, and finally by the Safety Authority. This structure is illustrated below:

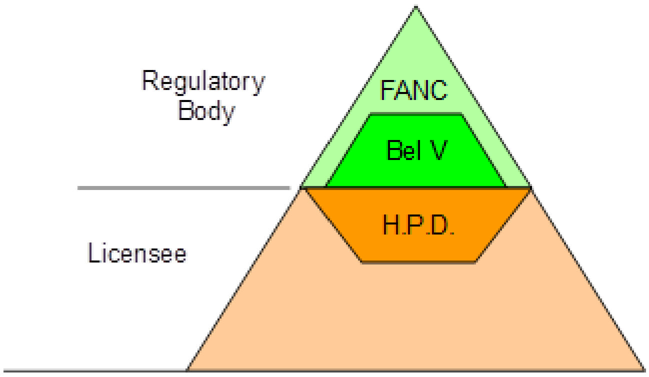

Figure 3 : 3-level control structure

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 the various organisations.

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

The GRR-2001 stipulates that the King is the competent Authority who grants the licenses for Class I nuclear facilities (which include nuclear power plants and research reactors), it also specifies a number of tasks to be performed by the Federal Agency for Nuclear Control, which may delegate tasks to Bel V to perform supervision activities of Class I facilities.

In this way, the regulatory work, and in particular the supervision and inspection of the operating organisation, is performed at two levels:

a) At the level of regulations and supervision:

The FANC is in charge of updating the regulations, of transposing the European directives, international treaties, and of maintaining the internal coherence of the regulations. To that effect, it makes proposals to its supervising minister (of Home Affairs).

As regards the general supervision of the operating organisation, the FANC and Bel V are informed of the organisation's operational issues and projects through the meetings of a "Contact Committee" composed of representatives from the regulatory body and the operator. This Committee meets twice a year on average.

The regulatory body also systematically holds a control meeting at the end of each core refuelling period, to evaluate the activities and results of that shutdown period. Unexpected visits are also performed. In case of significant operational problems (e.g. deformation of fuel assemblies, possible contamination of transport containers, …), or in case of safety issues raised for example by international OEF, specific meetings are held between the regulatory body and the operator in order to assess the technical problems and to consider and decide remedial action; these actions are in this way approved by the Safety Authority.

The FANC can also act as an arbitrator in cases where the operator deems that the technical demands of Bel V are unreasonable: after having heard the various technical standpoints the FANC can resolve about what is finally required.

b) At the level of the detailed technical analysis and the permanent supervision of the operator as required by the regulations.

When a licence for a modification of a nuclear power plant is applied for, Bel V is requested to review the Safety Report presented by the applicant, and to present its conclusions to the FANC. Using this safety review, the FANC can also propose additional conditions for operation that the Scientific Council may endorse. In this case, these operating conditions will be included in the licence (by Royal decree). The FANC and Bel V present the content of the safety review and the legal aspects, including proposals for additional conditions for operation, to the Scientific Council. If judged useful, the licensee concerned can be requested to provide specific information to the Scientific Council and respond to the latter's questions.

Before the installations are put into operation, the initial license must be confirmed by a second royal decree (see article 6 of GRR-2001), provided that the installations are subject to a fully favourable delivery, i.e. an in-depth verification of its conformity with the existing regulations, its license and the Safety Analysis Report, according to Article 6.9 of the GRR-2001. The delivery inspections and conformity checks are performed by Bel V, on behalf of the FANC.

Throughout the operation of the installation, the operator's Health Physics Department supervises nuclear safety and radiological protection, the department's performance being permanently supervised by Bel V (GRR-2001 - Article 23).

This permanent supervision in practice consists of systematic and periodic 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 visit.

The Bel V inspection reports of the nuclear power plants are systematically transmitted to the FANC.

After each core refuelling, Bel V verifies that the new configuration is acceptable, and follows-up the start-up tests, assesses their results, and authorises (through its delivery report) operation at nominal power.

All modifications are notified to Bel V. However, Bel V and the FANC will follow-up only the safety-related modifications.

Major modifications (power increase, use of MOX fuel, steam generator replacement …) may require, under the appreciation of the FANC, a procedure similar to that of the initial licensing, and sanctioned by a new Royal Decree amending the initial license.

Less important modifications are implemented by the licensee under the supervision of its Health Physics Department (HPD). Bel V is in charge of approving the final delivery of the modification proposed by the HPD. The Safety Analysis report is updated accordingly.

II.D.2. **Powers and Attributions of the Regulatory Body**

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.

The findings of the inspection visits and the observations made are recorded in the reports established by Bel V and transmitted to the operator; the latter implements then any necessary corrective action.

At this stage Bel V has only the power to make recommendations but 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.

The FANC nuclear inspectors are nominated by Royal Decree. They have the powers of enforcement inspectors; they can also intervene on the request of Bel V inspectors. The FANC inspectors can 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).

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 included in the License with the aim of improving safety.

Finally, if the licensee does not comply with the regulations or with its license, a process described in article 16 of GRR-2001 allows the FANC to propose the suspension or the withdrawal of the license, after advice of the Scientific Council. As for the granting of a license, the King is the competent authority to take such decision for NPPs.

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

a) The Safety Authority

The Federal Agency for Nuclear Control (the FANC) is an autonomous public institution with legal personality. The Agency is directed by a 14-headed Board of Directors; its members are appointed by the Federal Government on the basis of their particular scientific or professional qualities. In order to guarantee the independence of these directors, their mandate is incompatible with certain other responsibilities within the nuclear sector and within the public sector. The FANC is supervised by the Federal Minister of Home Affairs via a government Commissioner who attends the meetings of the Board of Directors. The Board delegates the management of the FANC to the General Manager.

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 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. Infractions with regard to the decisions of the FANC can be sanctioned.

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

Within the Board an audit Committee and a strategy Committee have been set up to prepare certain decisions. 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:

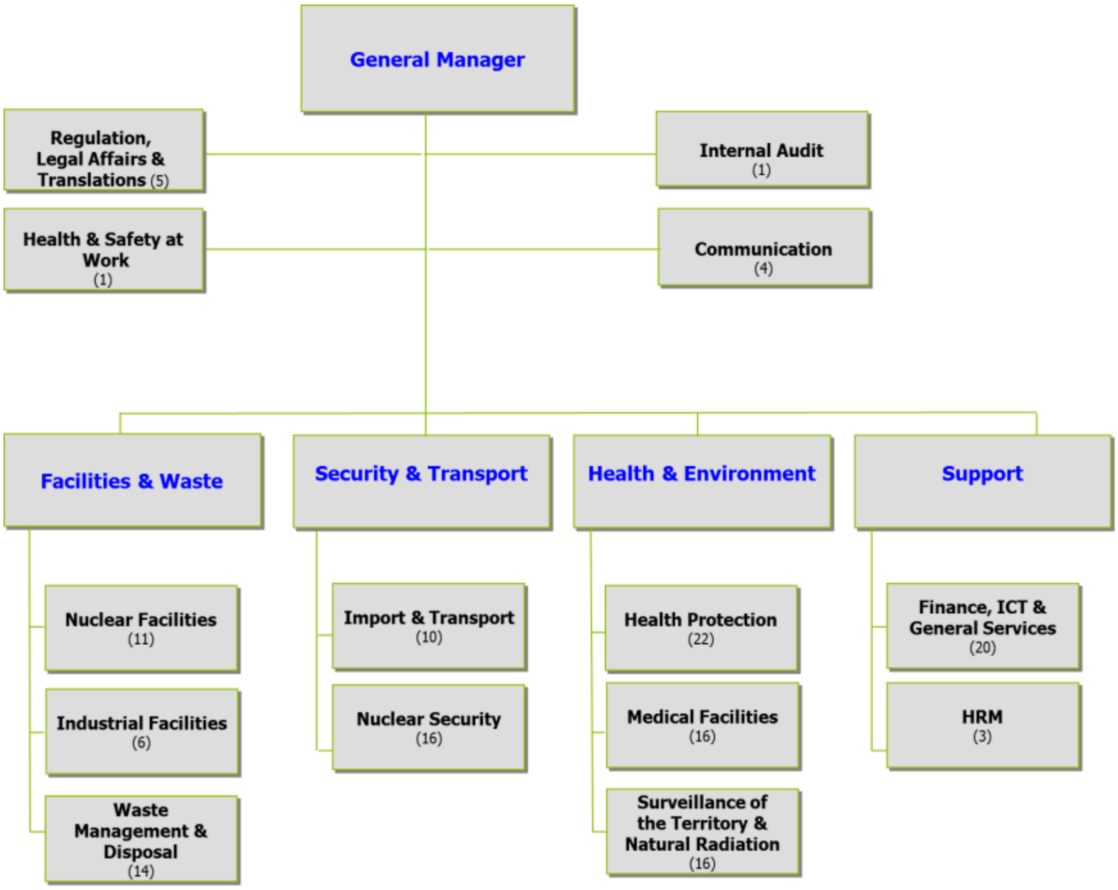

Figure 4 : Organisational chart of FANC

The missions of the department `Facilities & Waste' are specifically related to the nuclear industrial facilities, the management of the radioactive waste, and the recognition of qualified experts in health physics control.

- The first mission includes the inventory, the analysis and the evaluation of license applications. This mission consists in 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 license and the conditions attached to, 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 for the facilities dedicated for surface disposal of short-lived low- and intermediate-level radioactive waste and future possible geological disposal of high-level and long-lived radioactive waste.
- Finally, the department makes regulation proposals in its field of activities and develops the related 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 requiring the collaboration between several departments (horizontal activities):

- knowledge management at the FANC level;
- development and maintenance of the FANC Management System;
- coordination of FANC projects;
- coordination of international activities;
- human resources;
- finances ant Information Technology.

At present, the personnel of the FANC is composed of about 150 persons. 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 conforms 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.

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*" IP002-01 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 budget.
- *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. These policies are currently under revision in the framework of the post-IRRS action plan.
- the *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 according to article 73 of the GRR-2001, ensuring that an expert has at least three years of experience in the nuclear field before he/she can be recognised as expert. 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 as regards safety are: to manage the projects/missions (manage safety assessment projects and inspection projects), to perform the 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 directors 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 some 72 (68 full-time equivalent on 31/05/2016) university graduates (engineers and scientists), and recruitment is in step 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 examined, and also to the assessment of incidents or specific safety problems in the installations in Belgium or abroad (Barsebäck, Forsmark, Fukushima Daiichi…).

The inspections and analyses carried out by Bel V are invoiced to the operator on the basis of hours actually worked. This system is similar to that applied by, for example, the USNRC which, in addition to a set fee per installation, charges to the operators the time actually spent on their dossiers. In the next future, the hourly tariff of Bel V experts will be fixed by Royal Decree.

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, for the maintenance a technical and regulatory documentation.

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 from 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 director, 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 include also inspections in installations other than nuclear power plants, namely other class I facilities as well as class II and III facilities (universities, hospitals,…) having their own Health Physics Department.

The follow-up of all national and international projects linked to the operation of the installations is performed in the framework of the process "**Manage the projects/missions**".

At the national level, examples are the increase of the length of the cycles and the higher burn-ups, the power increase and the replacement of steam generators, the European "Stress Tests", the periodic safety reviews, 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, in order to define the new safety reference levels, in agreement with the FANC.

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.

The process includes Bel V activities in the frame of its participation in the national emergency plan at the level of the evaluation cell (see article 16, paragraph 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.

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 on services from outside specialists only very exceptionally (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 recent reactor pressure vessel flaw issue of Doel 3 and Tihange 2 reactors and, support in developing MELCOR input decks..

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

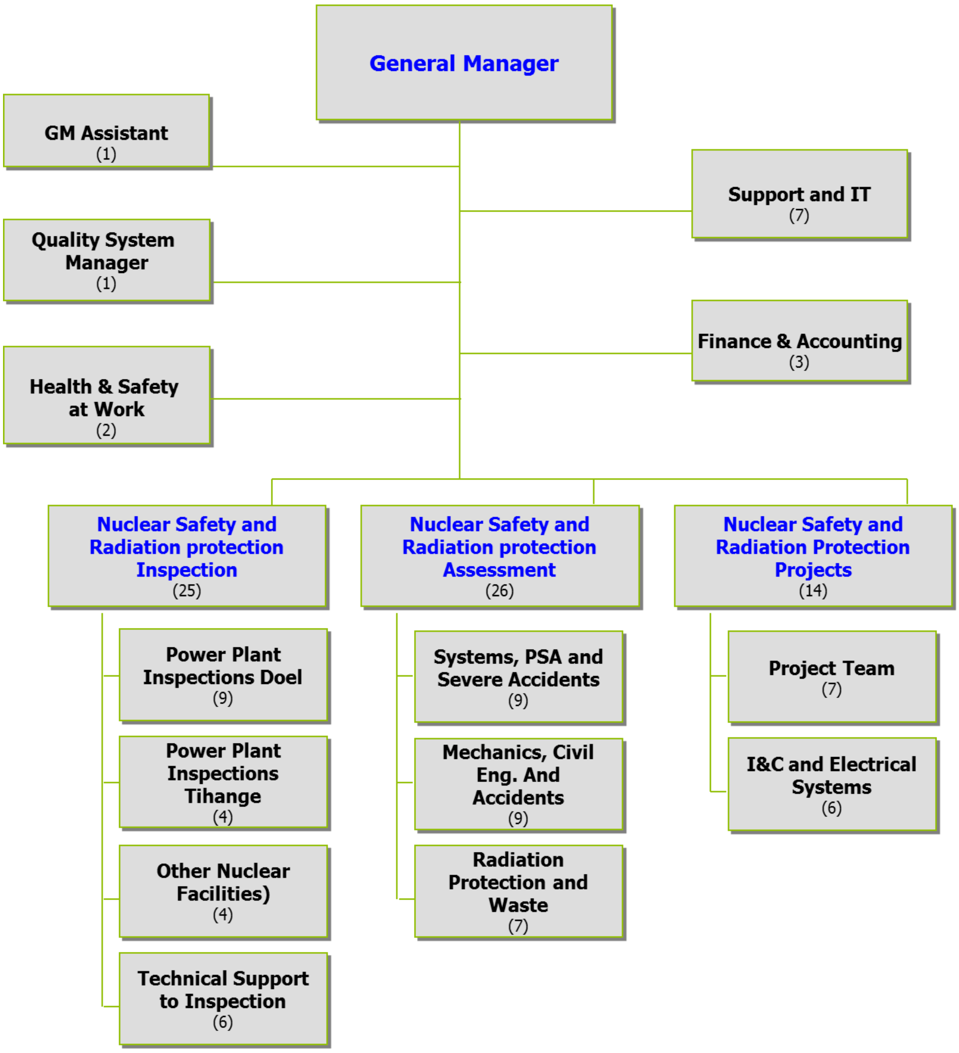

Figure 5 : Organisational Chart of Bel V

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

The Safety Authority (FANC) is a public interest body, with a large independency and 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. This report is referred to in FANC's annual report and also presented to the Parliament.

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. He promotes the use of nuclear energy, as does the Nuclear Forum - Forum Nucléaire, member of Foratom.

The organisations dealing with questions related to the use of nuclear energy, such as the "Centre d'Etudes Nucléaires" 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) report to the Minister of Home Affairs.

The Regulatory Body (FANC and Bel V) plays no part in nuclear energy promotion, but the FANC also has a mission to "stimulate and co-ordinate the research and development work"s. 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. **Relations between FANC and Bel V**

A 'Management Agreement' has been signed between the FANC and Bel V. This management agreement is concluded for a period of 3 years and implicitly renewed at the end of each period. It can also change/evolve in function of experience feedback, future needs or missions.

The main elements of this management agreement are given hereafter.

a) Operational and strategic objectives

By delegation of the FANC, Bel V is in charge of the following regulatory activities:

(1) <u>On site regulatory inspections and controls.</u>

An integrated control and inspection strategy is developed jointly by the FANC and Bel V. A 3-year programme is defined and communicated to the licensees. An annual planning for inspections and controls is derived from this programme. A revision of the programme is foreseen each year, in order to take into account experience feedback from the previous years.

The annual control programme of Bel V is approved by the FANC.

Bel V is in charge of the surveillance of the good working of the Health Physics Department of the licensee.

Bel V is in charge of setting up inspections methodologies and evaluation processes for the different types of facilities it supervises.

Bel V informs the FANC on its findings. 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 controls, and draw up the lessons learnt of the controls it has performed.

(2) <u>Delivery of new installations</u>

Bel V is in charge of the supervision of the delivery of new or modified nuclear installations. An acceptance report is sent to the FANC.

(3) <u>Safety assessments and environmental impact assessments.</u>

Bel V is in charge of the review of the safety analysis of the facilities it supervise.

Bel V is in charge of the verification of the safety analyses submitted by the licensee in the frame of the periodic safety reviews of its installations.

Bel V presents the results of the safety reviews to the Scientific Council of the FANC.

(4) <u>Emergency preparedness and response</u>

Bel V collaborates with the FANC for technical and radiological evaluations in the different cells set up in emergency planning and response: The measurement cell (CELMES) and the evaluation cell (CELEVAL).

In particular, 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.

(5) <u>Security of nuclear installations</u>

Bel V is in charge of reviewing security plans on request of the FANC and of the associated on-site inspections. Bel V is also in charge of the assessment of the modifications of the security plans.

b) Transverse processes

A collaboration between FANC and Bel V is established in the following areas:

(1) <u>Advice on regulation proposals</u>

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

(2) 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.

(3) Research and Development

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

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

A collaboration will be established in the field of knowledge management.

c) Funding of Bel V

Bel V is a non-profit organisation. It is funded by:

- The FANC;
- The licensee for the on-site controls and safety assessments it performs, according a pre-defined hourly tariff. This tariff will be fixed by royal decree in the future.

II.D.7. Information of the public

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

Interested parties that are informed by the FANC comprise:

- 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 ("Belgish 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 the Parliament's members to the minister;
  - the government commissioner who attends the meetings of the Board of Directors;
  - the annual report submitted to the parliament;
  - the follow-up by the parliamentary commission of Home Affairs;
- the licensees: several formal and informal communication mechanisms are in place;
- 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 licenses to local authorities, to some federal administrations, to the civil security, 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. Parliament members can also ask questions to the FANC supervising minister.

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. Flash news are also regularly published on the web site.

The results of the measurements performed by the TELERAD (See article 16 of the CNS) network are available on the FANC web site as well. This gives the opportunity to all interested parties to have an on line 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). The regulatory body has set up a convention with the licensees of class I facilities and of highest risk class II facilities to use INES as a communication tool to the public. This convention is on a voluntary basis, and all the concerned licensees participate to it. Events that are ranked on level 1 or higher on the INES-scale are published on a dedicated web page on the web site of the FANC. This open and transparent communication of events using the INES-scale, contributes to a better understanding of the public on the safety significance of events, as well to the trust building of the regulatory body.

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 : http://www.fanc.fgov.be/fr/page/rejets-d-effluents-radioactifs-des-etablissements-nucleaires-de-classe-i/1545.aspx (in French).

Publications related to the CNS process

After each review meeting, 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 6th review meeting can be found (in French) on the following web page : http://www.fanc.fgov.be/fr/page/la-6eme-reunion-pleniere-des-pays-signataires-de-la-convention-sur-la-surete/1531.aspx

II.D.8. **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, most of them implying activities related to the Fukushima Daiichi accident.

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 with Bel V 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 also 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 impacted significantly the work of WENRA under the impulse of ENSREG, namely 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 bilateral agreements are in force and the FANC has extended collaboration with foreign regulatory bodies, in particular with his neighbouring countries (France, the Netherlands and Luxembourg). Among others, this cooperation includes sharing of information, technical meetings, attendance at inspections on the field, and exchange of experts

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. Exchanges of observers with the French Safety Authority (ASN) for emergency planning exercises are organized on a systematic basis, as well as participation of inspectors to cross-inspections.

II.D.9. **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.

Article 2 of the Royal Decree of 20 July 2001 (GRR-2001) defines the "Licensee" as follows:

"Any natural or legal person who is responsible of a facility or a work activity that is subject to licensing or reporting according to chapter II."

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 power plants the Royal Decree of Authorisation requires conformity with the Safety Analysis Report and with the document established in implementation of Article 37 of the Euratom Treaty.

This authorization sets that modifications of the descriptions included in the SAR are nevertheless acceptable if they improve the safety of the nuclear installations or have no impact on their safety.

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).

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.

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 23.8 of the GRR-2001 specifies a number of specific tasks in that respect.

As referred to in Article 8 of the present National Report, a Bel V inspector is assigned to each nuclear power unit. The inspection visits that he makes at the unit (where he has total freedom of movement, regardless whether or not he is accompanied by unit personnel) take up about 25% of his working time; the rest of the time, the inspector is at Bel V offices where he follows-up the inspections, writes the inspection reports, collects and analyses relevant information, discusses with the technical experts and exchanges information and gets feedback from the other nuclear power units. In this way the Bel V inspector can verify daily how the operator ensures his obligations and responsibilities.

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

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

"We attach the greatest importance to the protection of all members of personnel involved in operation of our nuclear power plants, of the public and the environment. Therefore, we actively support a strong nuclear safety policy in all phases of the operating processes of our power plants.

Together with our partners and contractors, we work towards the practical application of this 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

Values and Behaviours promoted by the Nuclear Safety Policy Declaration

The first principle stated in this Nuclear Safety Policy is "Safety = the first 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 explain 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.

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 Internal Code and the Reference for Nuclear Safety 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 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.

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 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, 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 extend. 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.

Human performance programme within 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 Electrabel are managed on a three level structure:

a) Nuclear Generation level and
b) Nuclear Power Plant level.
c) Electrabel Corporate Nuclear Safety 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. Noteworthy the corporate level includes the following departments:

   - The Department Nuclear Design & Projects:
     - 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 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.
     - Ensures the development, implementation and evaluation of the experience feedback process.
   - The Corporate department "Nuclear Liabilities & Projectlead DSZ + D&D Doel 1-2" is active in the following fields :
     - Management of nuclear liabilities.
     - The request for final shutdown of nuclear activities.
     - The organization of DSZ and D&D for Doel 1-2.
   - The Corporate department "Nuclear Assets & Support Management" is responsible for the following activities :
     - Strategic Asset Management of the nuclear facilities,
     - Quality Assurance (QA) & Nuclear Generation Management System (NGMS),
     - Competence Management and Training (Office for Competence & Knowledge Management),
     - IT and IT Security (Office for IT Nuclear),
     - Document Management,
     - Performance, Risk & Environmental Management

The Human Resources Department is located on the corporate level. The activities of Human Resources are mostly focused on the competency development and knowledge management of the personnel of Electrabel.

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.
- **Engineering Support** is in charge of the management of the modifications and projects on site and of the management of the generic issues and long-term concerns. Furthermore the Engineering Support department has the competency of Design Authority, validating the conformity of proposed changes with the overall safety design basis.
- The **Continuous improvement** department is in charge of Human Factors and operational Experience activities
- The **Care** department is in charge of surveillance in radioprotection (Health Physics Control in the sense of the GRR-2001), 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 representative of the centralized Health Physics Department (as required by the regulations) and has the appropriate delegation from this department to perform the formal approvals required by the regulations. It ensures the respect of the nuclear safety culture by independent technical checks and thus forms the link with the Electrabel Corporate Nuclear Safety Department (as mentioned before).

c) The Electrabel Corporate Nuclear Safety Department (ECNSD): this department is in charge of supporting the increase of the effectiveness of the management of nuclear safety in the nuclear power plants. The five processes ECNSD is involved in are determining nuclear safety strategy, providing expertise and independent monitoring of nuclear safety coordinating actions regarding nuclear safety, reporting on nuclear safety, and providing operational support for the nuclear power plants. The ECNSD department reports directly to the Health and Safety and Nuclear Safety Officer, who is the head of the Health Physics Department ("Service de Contrôle Physique/Dienst voor Fysische Controle") according to article 23 of GRR-2001. Through the Health and Safety and Nuclear Safety Officer, ECNSD reports directly to the CEO.

The figure below shows the organisation of ECNSD, the functional links with the Care departments on the two sites and the corresponding delegations.

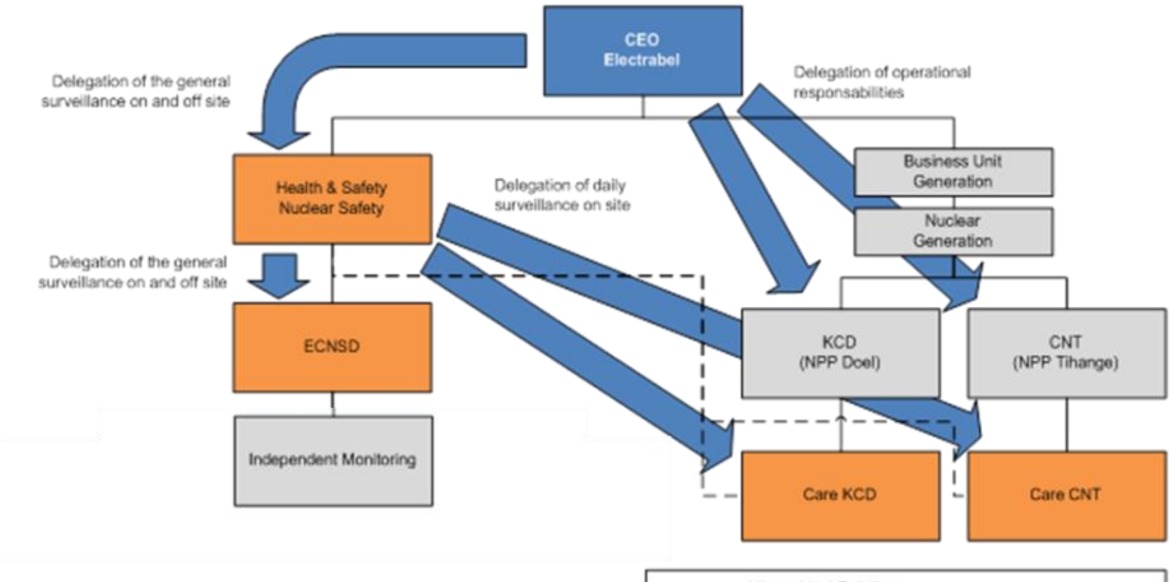

Figure 6 : Organisational structure of Electrabel and delegation of responsibilities

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.

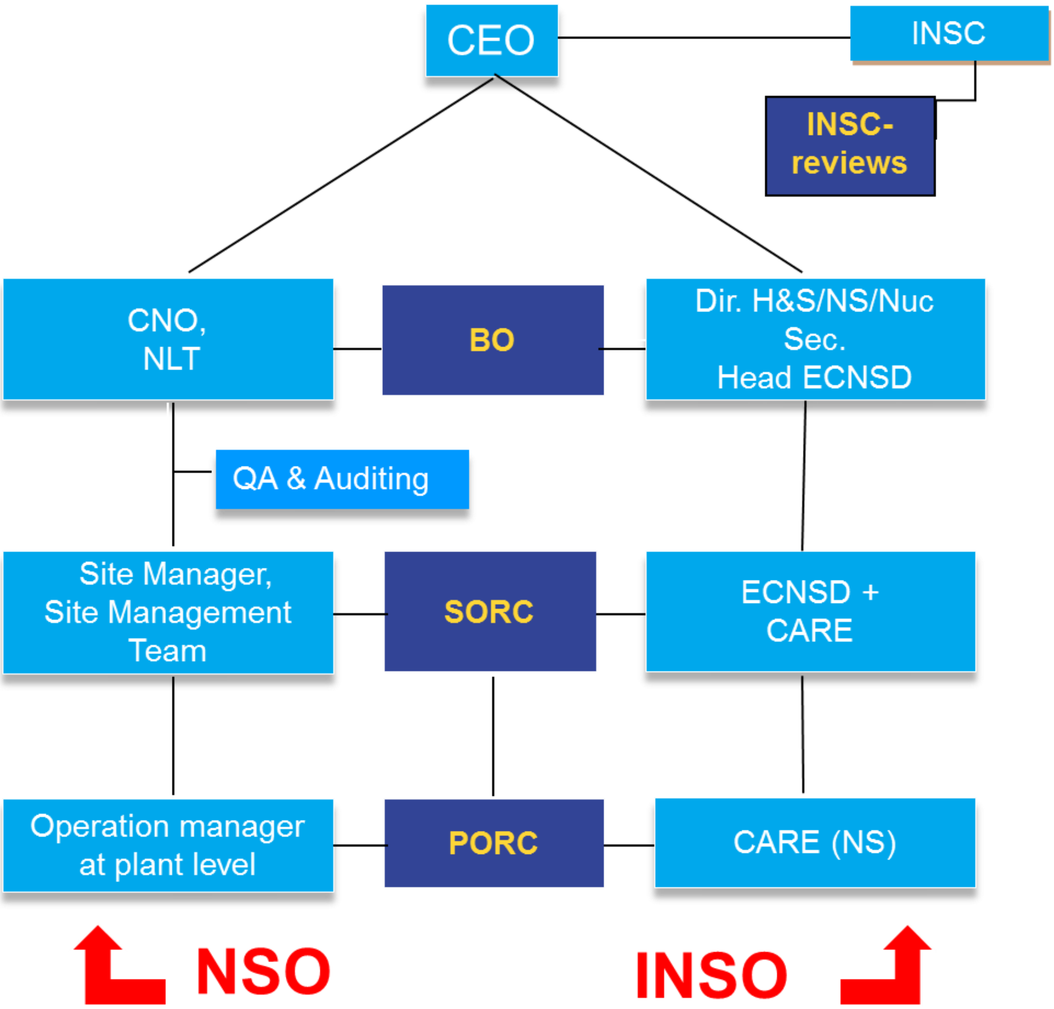

Figure 7 : Internal Safety Assessment

The left-hand side of the figure shows the operational line, which has the final responsibility for nuclear safety. The Nuclear Safety Oversight **(NSO)** within the operational line is not described further in this procedure, but broadly speaking covers:

- the oversight and monitoring at site and corporate levels by the operational line itself, by means for example of the periodic **process reviews** and **self-assessments** which are conducted by the process managers and/or line management;
- the **QA Audits** carried out by the "Quality Assurance & NGMS" section. The "Quality Assurance & NGMS" auditors have the task of checking compliance of the operational procedures with the requirements of the Final Safety Assessment Report (FSAR), the internal Referential for Operational Nuclear Safety (RONS), and compliance of the activities carried out with the applicable procedures and instructions.

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.

The diagram also shows the NS oversight committees (PORC, SORC and Business Oversight (BO)) for the various levels. Members of the INSO-line participate also to these committees and present their nuclear safety messages/conclusions.

In the specific Belgian context, the **INSO** is a component of the activities of the ***Health Physics Department*** **(HPD)**, as described in Article 23 of the GRR-2001. The relationship between HPD and the internal INSO is outlined in the figure below:

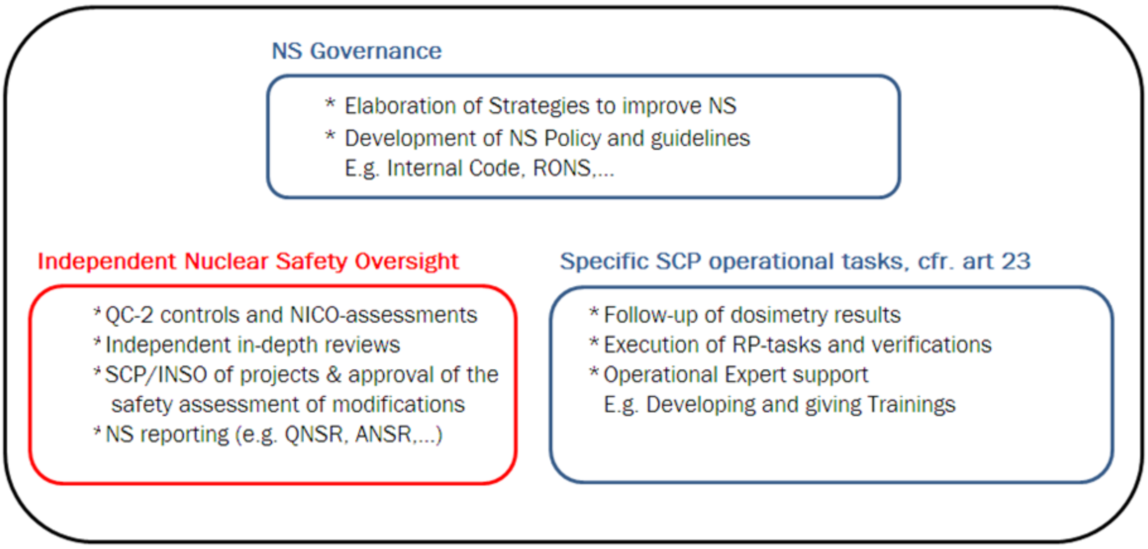

Figure 8 : Health Physics Department activities

II.F.2. **Research Reactors**

The general management 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 asked for security and physical protection aspects. In 2010, this charter is completed by the publication of management expectation on the use of procedures.

These general statements are further put in 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. This is a complete 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. This reporting is already a number of years in operation and is considered as very valuable. Based on this experience, a reporting system for others installations of the SCK•CEN (including the BR1 reactor) is set up. 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 is encouraged to report facts with a potential interest for other, 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 ways for risk analysis, for use during the preparation of a task or just before and 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 50 years, which means that people involved in the design and building of the installations are no longer available. In this way it is very important to keep all documentation about the installations in good condition in such 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 is under development, based on the IAEA Standard GS-R-3 (The Management System for Facilities and Activities).

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 specific missions that are reproduced hereafter:

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 still more integrated approach in the field of nuclear safety and radiation protection. A 3 years based programme is defined and communicated to the licensees. An annual planning for inspections established, based on this programme. A revision of the programme is foreseen each year, to take into account experience feedback from the preceding years. The process is explained in more details on the FANC web site (in French and Dutch): http://www.fanc.fgov.be/fr/page/strategie-d-inspection-et-de-controle-integree-ici-pour-la-periode-2015-2017-pour-les-etablissements-nucleaires-de-base/1783.aspx As a matter of fact, 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, in the course of the years, developed an inspection and safety assessment strategy aiming at the assessment of how the licensees manage safety, with specific emphasis on the implementation of the GRR-2001 and of the licenses 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 supported by strong programmes of expert initial training and retraining, of operating experience data collection and analysis, of specific research and development activities.

This strategy is imbedded in the various processes of the ISO-9001:2008 quality system of Bel V (certification obtained in the beginning of 2010), 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

Main activities of Electrabel are the generation and commercialisation of electricity and gas in Europe. In Belgium, 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. The installed power of Belgium's nuclear generating units accounts for some 40 % of all installed power 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 4500. 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 has also 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, if an authorized person has ceased during four months or more performing 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 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.

A Job Atlas Handbook has been developed at the Electrabel Corporate level. The Job Atlas Handbook lists all of the functions within Electrabel Corporate, as well as the corresponding competency and skills required. A detailed description has been defined for each function and a link has been made with the competences necessary to carry out each of these functions.

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

Every staff of 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 in the Job Atlas Handbook 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:

- Training rooms equipped with blackboards, PCs, etc.
- A miniature size version of a reactor unit
- 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 PID 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 fire fighting

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 of our activity.
  - **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.
  - **NTP Generation programme:** This program was organized for the first time in 2011 as NTP Track bis. Since 2012, it is called NTP Generation. It is specifically dedicated to more experienced engineers working on a nuclear power plant who have not yet had the opportunity to follow the NTP Juniors. The program with duration of 210 training hours deals with nuclear theory and is concluded by a formal technical test.
  - **NTP technicians:** in 2012, the Group has decided also to develop a training programme for technicians. The pilot session of this program has been started in 2016.

(5) Contractor Training and Qualifications

Contractors are responsible for the training of their own personnel. Nevertheless, 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.e). 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.

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 of the FANC (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:

	ECTS[2]
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 7 : BNEN Curriculum

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

In addition the SCK•CEN Academy also offers more specialized training courses for nuclear professionals:

- Radiation protection: initial (9 days) and refresher courses (5 days) in radiation protection and the Radiation Protection Expert course (120h) for NPPs in Doel and Tihange;
- Nuclear reactor theory: 90h course for reactor operators of NPP Doel and two-week contribution to the Nuclear Training Programme of ENGIE;
- Nuclear emergency management: participation of NPP personnel in these open courses which are organized on an annual basis and supported by the NERIS network.

Parallel efforts were also made to create a European network of academic institutions active in nuclear engineering education, to establish links with the International Atomic Energy Agency (IAEA), with the Nuclear Energy Agency of the OECD (NEA), and other international bodies like the World Nuclear University (WNU). Today, the European network 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. Its name is ENEN (European Nuclear Education Network). It is legally based at the premises of the "Institut National Supérieur des Sciences et Techniques Nucléaires" (INSTN) at Saclay (France), and 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.

[2] 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 Licensee (Electrabel) 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 our performances.
- 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
  - Defines the corrective actions to be implemented to avoid recurrence of the event
  - Second layer analysis HU

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):

- <u>Management expectations</u>: 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).
- <u>Tasks observation</u> : 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
- <u>Communication:</u> Specific HU communication is achieved by using electronic Public Address display, newsflashes, films, magnetic posters and during training sessions.
- <u>Training</u>: 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)

a) Human performance action plan

Tihange NPP has established a human performance (HU) improvement plan for the period covering 2010-2012. This plan is built on the following elements:

- HU project steering committee: this new committee meet every two months and directs all actions related to the HU project (set targets and monitor progress) and ensure consistency of actions within the different departments (e.g. communication, training courses).

- Training of personnel and contractors : All personnel has participated to the one day training to understand why human error is natural and how to prevent it (50% theory) and then apply acquired knowledge on the human performance simulator or on the full scale simulator (50% practice). A meeting with contractors' managers (boss to boss meeting) has been organized to explain the HU action plan. Team leaders did follow a specific HU training with exercise on the human performance simulator. Training for contractor's workers was incorporated into the nuclear safety refresher training of two day with practice on the human performance simulator.
- Coaching Managers in the field: Managers (executives and supervisors) did receive an individual coaching to perform task observations (external coach). A new booklet outlining the expectations to perform a good task observation has been edited and used during the training. The task observation form has been simplified.
- Communication: A poster campaign on the use of HU tools was launched in 2011. Communication has been made around the new booklet outlining how to perform a good task observation. Specific HU communication is achieved by using electronic Public Address display, newsflashes, films, magnetic posters and during training sessions.

The plant manager requests from each department a specific yearly human performance (HU) improvement plan.

A pilot project of "HU champion" network has been created in the department Care (Environment, Radiation Protection, Industrial Safety, Nuclear Safety, Fire Protection, and Emergency Preparedness). They meet two to three times a year. They did receive a specific two days training course. Each HU champion supports the use of HU tools in his or her team. In function of the results this network will be extended to all departments.

While the HU tools are common at site level, the way to apply them in practice has been described specifically for the main jobs (operator, chemist, electrician…).

At Doel NPP, each department has also established its own HU improvement plan. For the last 3 years, these plans were built around the following elements:

1.	**FUNDAMENTALS (requirements for basic activities + use of HU tools): initial drafting and regular updating.**
2.	**Training/knowledge of FUNDAMENTALS for all staff is ensured**
3.	**HU COACHING PROGRAMME and OBSERVATION PROGRAMME is implemented for Middle Management and technical staff.**
4.	**EVENTS (Incident Reports) (regarding Fundamentals) are periodically analysed, communicated (one-page slides) and listed, summaries are drafted.**
5.	**OBSERVATION REPORTS (regarding Fundamentals) are periodically analysed, communicated and listed, summaries are drafted.**
6.	**SELF-ASSESSMENTS are organised per team, integrating input from an analysis of the incident reports (see above under 4) and the observation reports (see above under 5).**
7.	**ANNUAL OBJECTIVES continuing from the results of the self-assessments (see above 4, 5 and 6).**
8.	**Per team, ANNUAL OBJECTIVES are SPECIFIED and each team defines 1 specific action for improving industrial safety. This objective is monitored closely by Line Management.**
9.	**KPIs regarding QUALITY OF PROCEDURES (content and use) are elaborated and discussed with the teams.**
10.	**FOLLOW-UP and CHALLENGING of objectives and performance of teams on the basis of challenge times by line management (F-2-F-meetings, oversight meetings, etc.).**

b) 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.

c) *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.

d) *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.

e) *Human Performance Simulator*

Tihange and Doel NPP are equipped with their own "human performance simulator". This training facility is considered among worldwide nuclear operators as an excellent training tool to model safety behaviours (good practice OSART). 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 9: 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

According to the action plan on safety culture, training was given on safety, with special attention on reporting of incidents and unusual events. 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). In 2009 the operators received also a number of training days at the nuclear power plant of Doel. 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 or 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 person 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 made by an inspector or a safety analyst during any contact with a licensee[3]. 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[4].

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 synthetic report (monthly meeting FANC-Bel V). 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 problem 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.

In 2015, an evaluation of the process was conducted after 3 years of application of the safety culture observations process. The evaluation highlighted that the quality of observations shows an improving trend and that the system enables to cover a larger scope of safety culture attributes. However, the reporting process to the licensee needs to be improved in order to deliver clear and useful messages. Such clear and useful messages should lead to tangible actions from the licensee. Results of the yearly safety culture analysis feed the inspection program.

[3] 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…

[4] 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*.

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.H.4. **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, 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 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, 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, Environmental protection and Economic considerations.
- 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 Electrabel.

- To deploy appropriately its resources, Electrabel implements the requirements of its management system following a graded approach.

The implementation of this management system allows 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.

Improvement plans include plans for the provision of adequate resources.

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

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
- Electrabel's Internal Code for Nuclear Safety
- Electrabel's Reference for Operational Nuclear Safety
- Electrabel's Nuclear Generation Management System Policy Manual
- Execution documents

(1) <u>Electrabel's Internal Code for Nuclear safety and Reference for Operational Nuclear Safety</u>

This two documents are developed and maintained by the Electrabel Corporate Nuclear Safety Department (ECNSD).

The Internal Code for Nuclear Safety is the cornerstone of the Electrabel internal governance regarding Nuclear Safety. It aims to:

- Support Electrabel in striving for operational excellence for all its Belgian nuclear activities, peculiarly fostering on the continuous improvement of its Nuclear Safety performance;
- Define rules that support the Electrabel management system to comply with the Belgian legal and regulatory requirements, as well as the ENGIE Group requirements regarding the management of Nuclear Safety;
- Define the internal stakeholders' roles and responsibilities with regard to Nuclear Safety at a corporate level.

The internal code for Nuclear safety is approved by the person in charge of the day-to-day management of Electrabel.

To meet its commitment to strive for excellence in all of its nuclear processes and activities, Electrabel requires them to conform with requirements additional to the legal and regulatory ones. These additional requirements are identified in the document entitled "Reference for Operational Nuclear Safety". the Reference for Operational Nuclear Safety integrates the quality assurance requirements for the processes of the management system. It complements the Internal Code and is approved by the Head of H&S/Nuclear Safety/Security.

Each Electrabel entity must translate the directives and general principles of the Internal Code into local procedures and instructions taking into account the QA minimal requirements levels defined in the Safety Reference.

(2) Electrabel's Nuclear Generation Management System Policy Manual

The "Nuclear generation management system Policy Manual" gives a more detailed description of Electrabel's Nuclear Generation integrated management system to achieve its objectives and to ensure and to improve safety at Electrabel's 3 sites, the Doel and Tihange power stations and the Nuclear Corporate headquarters. This management system is process-based.

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

(1) Nuclear safety oversight

Monitoring

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.

Self-assessment

Management at all levels (Senior Management, Line Management and Process Owners) carry out self-assessment with the objectives to:

- Evaluate the performance of work;
- Prevent, identify and correct weaknesses that hinder the achievement of Electrabel's objectives;
- Improve the management system;
- Enhance the Nuclear Safety culture and the effectiveness of processes and activities.

Inspections and Audits:

A comprehensive system of planned and periodic inspections and audits is carried out to verify compliance with all aspects of the management system and to determine the effectiveness of the management system to provide adequate confidence that a structure, system, or component will perform satisfactorily in service.

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 Electrabel to be accomplished and the Nuclear Safety policy to be met.

(2) 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 Electrabel Corporate Nuclear Safety Department are clearly defined. Independent oversight provides the 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

Nuclear Safety Committees

Within 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 Electrabel:

- The Plant Operating Review Committees (PORC),
- the Site Operating Review Committees (SORC) and
- The Independent Nuclear Safety Committee (INSC)

(3) Regulatory control activities

As regards the regulatory control activities, AVN (now Bel V) examined in the frame of the licensing process of each unit the quality assurance system to be implemented during the design, construction and operational phases (chapter 17 of the Safety Analysis Report, Electrabel Internal Code, ...) and verified the practical implementation of the various regulations (10 CFR 50 Appendix B, ASME code,...) throughout these phases. As regards pressure vessels for which the ASME code or the conventional Belgian regulations (RGPT) are applicable, the intervention of an Authorised Inspection Agency (AIA) is required as an independent inspection organisation, and AVN has taken into account the results of those inspections.

II.H.5. **Research Reactors**

The SCK•CEN has a formal quality assurance system which includes a number of services such as production of radioisotopes and the irradiation of silicon. The system is certified for this services. Reactor operation procedures are considered as work instructions. This has the advantage that these procedures can be updated quickly. According to the legal requirements an integrated management system (IMS), based on the safety guide GS-R-3, is under development. A number of important processes, such as the management is already included. The IMS will be gradually extended to include all important processes for the reactors and also for the other installations of the SCK•CEN.

II.H.6. **Activities of the Regulatory Body**

During power plant operation, Bel V performs systematic inspections, including some dedicated to quality assurance procedures assessment during operation. The quality assurance aspects are also reviewed during examination of modifications to the installations, incident reports, etc.

In 2010, FANC and Bel V asked the licensees of nuclear facilities (including the NPPs and RRs) to perform a gap analysis between their management system and the requirements of the safety guide GS-R-3. Since the SRNI-2011 became 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 guide 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 in compliance 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.

II.I. 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.I.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.

More recently, the table of content of the SAR was 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) <u>Rules followed up to 2007</u>

The Royal Decree of Authorisation 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 obligatory.

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. Both the scope and the methodology are based on the approach adopted by the IAEA by the use of 14 Safety Factors, followed by a Global Assessment.

The objectives of the safety review are multiple. In the review, the operator should assess 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.

c) During operation of the installations

Experience feedback leads the operator to envisage modifications of the installations or launch major projects such as replacement of the steam generators or power increase. These activities are carried out in addition to those related to the periodic safety reviews.

The proposals for modifications to the installations are examined by the Health Physics Department of the operator, who discusses them with the Bel V inspector. Each proposal is classified into one of the three following categories:

- 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 license application, and follows a licensing scheme similar to that described in section II.C.7: The safety analysis performed by Bel V is presented to the FANC. The results of this analysis 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. The implementation of that modification will be authorised by the Health Physics Department. Bel V verifies the conformity with the Royal Decree of Authorisation.
- 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. After approval by the departments involved, the proposal is submitted to the management of the licensee, who can decide to continue final studies for the proposed modification. In the next phase, studies are completed and approval of both the Health Physics Department and of Bel V is sought to prepare the implementation of the modifications. The proposal is thus also examined by the inspector of Bel V, and by Bel V's technical responsibility centres, which may result in amendments being requested to the modification file. Further activities then imply the implementation, and testing of the modifications. Commissioning of the completed

modification is subject to a positive delivery report, issued after validation of the modification and re-qualification of the portion of the installation that was modified, plus 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 and Bel V can then issue a final delivery report. Such modification can either be hardware modification or 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 pages of the Safety Analysis Report to be updated**.**

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.
- 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 Engineering (TE), on behalf of the utility 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.

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 operation 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.I.2. **Research Reactors**

a) Main Results of Continuous and Periodical Safety Monitoring

During the operational lifetime of the installation modifications may be deemed necessary.

The modifications are treated with the same process as above described for the NPPs.

Experimental devices are not considered as modification of the reactor. A dedicated step wise approval system is developed. 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.

b) BR1

The previous (2006) safety review of BR1 included four topics:

- A programme for the modernization of the fixed radiation monitoring systems has been defined.
- A seismic qualification has been performed. The reactor can withstand an earthquake that is expected with a frequency of one every 10.000 years. The main issue was to prove that the loose staked graphite pile would remain intact and would not show displacements that could prevent the fall of a control rod. This point could be proven.
- A few years ago an increased iodine release, still within operating limits, was observed. A number of fuel channels were unloaded and some failed fuel elements were found. An investigation programme was started in order to find the root cause of these failures. These can be attributed to the long-time slow interaction between the metallic uranium and the aluminium cladding.
- The study of the consequences of a full electrical black out. Although the reactor needs no active cooling after scram, one loses the readings of the instrumentation and it is difficult to have a good knowledge about the situation. Therefore the number of instruments connected to the battery backup system will be increased.

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 planning inside BR1.

c) BR2

BR2 underwent from 1995 to 1997 a thorough refurbishment. The second beryllium matrix was nearing its end of life at that time and it was decided to replace it. A matrix was available from a zero power mock-up of BR2, called BR02, which was no longer in use. This BR02 matrix was fully qualified for use in BR2 and could be used for BR2 without any problem. According to the licence the matrix has to be inspected on regular intervals to follow cracking. Due do 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 between 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 cm² for the most irradiated channel.

In case of replacement of the matrix, an inspection of the vessel is also required by the licence. In fact, this is the only occasion when the vessel wall is accessible from inside. For the inspection of 1996, a fracture mechanical calculation of the vessel was made. However, the vessel is made of aluminium 5052-0 alloy. Knowledge about this material in irradiated condition is limited. Therefore it was decided to cut a number of samples out of the shroud, which is made of the same material and has received nearly the same irradiation dose. Out of these samples, tensile and fracture toughness test pieces were made. Some samples were immediately tested. The others were loaded in irradiation baskets in the reactor and a number of them will be tested on predefined time intervals. In this way a material follow-up programme for the vessel is established. The conclusion of the latest tests performed during the periodic safety review of 2006, was that the material of the vessel has a sufficient mechanical resistance to at least 2026. Before that time a set of new samples needs to be unloaded and tested.

As a consequence of the periodic safety review of 2006, two important modernizations were made: the replacement of the control rod drive mechanisms with the position indicators included and the replacement of the cadmium neutron absorbers by hafnium.

BR2 undergoes at present another thorough refurbishment. As explained above, according to the licence the beryllium matrix has to be inspected on regular intervals to follow cracking. The third beryllium matrix was nearing its end of life and it was decided to replace it. A new matrix has been designed identically to the actual matrix. The loading of the new matrix has been tested in the mock-up of BR2.

As explained above, in case of replacement of the matrix, an inspection of the vessel is also required by the licence. Based on the conclusion of the vessel assessment program made in 1996 and taking into account the results of the vessel inspection in 2015, it can be concluded that the reactor vessel can be further used for the expected lifetime of the fourth matrix.

The last important modifications in the framework of the refurbishment and the periodic safety review are: the modernization of the chain for power control, the physical separation of redundant cables, the replacement of the secondary piping and the removal of the beam tubes.

The current safety review of BR2 includes the following important topics:

- At the level of review of the Plant Design, a link is made with the actions resulting from the Stress-tests.
- Also, a project has been set-up to deal with ageing and long term operation, called Plan Asset Management (PAM). It consists of 3 phases: Asset Configuration Management (ACM), Installation Concept Management (ICM) and Workorder Management & Skills (WMS). The actual status of the SSCs and their qualification is included in this PAM project.
- A revaluation of the deterministic safety analysis is performed by identifying and performing better and more recent methods of analysis, which should eventually lead to an update of the safety analysis report.
- In addition, the probabilistic safety analysis is updated, extended and assessed. The outcome will be taken into account in the PAM-project.
- A revaluation of external hazards has been extensively performed in the framework of the stress-tests. The current safety review focusses on internal hazards and more specifically fire, explosion and flooding.

II.J. 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.J.1. Regulations

Chapter III of the GRR-2001 deals with radiological protection.

Article 20 of this Royal Decree sets among others the fundamental principles: justification of practice, optimisation of protection and individual dose limits. Other Articles of that chapter are described in Article 7, section II.C.3 of the present National Report.

Article 23 of this Royal Decree describes the key role of the Health Physics Department (HPD). This department is, in a general way and amongst other duties, responsible for the organisation and the supervision of the necessary means for operational radiological protection, including keeping records of radioactive releases.

II.J.2. 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). Let us bear in mind that 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.J.3. 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 the licensee 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*

(1) <u>Dosimetric results</u>

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.

The figure below 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, what introduces variations on the annual collective doses. Another factor of variation is the cumulated dose due to the replacement of steam generators. 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.

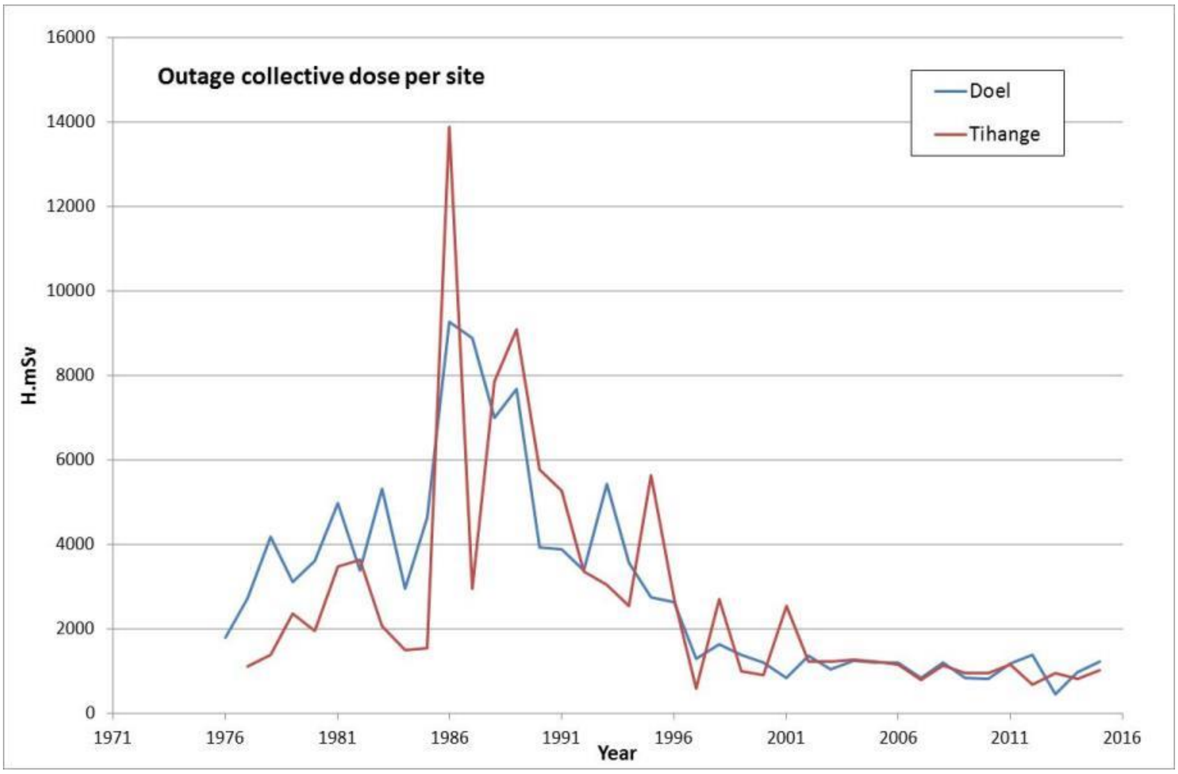

Figure 10 : Collective dose per outage

With those dose figures, Doel NPP ranks amongst the WANO best quartile for the Key Performance Indicator (KPI) Collective Dose Exposure (CRE) since a long time ago. Additional effort provided by Tihange NPP allowed to join this group late 2008.

The years 2013-14-15 are characterized by some unusual annual and outage collective radiation exposure values because, because of the following circumstances : vessel indications for Doel 3 / Tihange 2 in 2013 and in 2014, temporary freeze of the concrete conditioning of radioactive waste at Doel, due to an unexpected alkali-silicate reaction, outage planning rearrangement in order to meet the grid constraints during winter, and late preparation of the long term operation for Doel 1 and Doel 2.

Actual individual exposure of workers amounts to an average of ~ 0.5 mSv per year. The dose constraint of 10 mSv was not exceeded anymore since 2006.

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 time of exposure,

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

(2) Reduction of the source term

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, 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 but one does not observe any decreasing trend of the source term, because of the inadequate operational conditions during the extended shutdown caused by the vessel issue. The project considered for the unit Tihange 2 has not been started, taking into account the remaining operational lifetime prescribed in the Phase Out Law.

In the period 2000 - 2007, statistics of fuel failures seemed to indicate a slight increasing trend. Therefore 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.

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 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 %.

(3) 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, 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.

In 2015, the Doel NPP began the progressive replacement of the electronic personal dosimeters (EPD's). this replacement should be completed with the units Doel 1 & 2 in 2016.

(4) 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.

(5) Reducing time of exposure

Reducing the time of exposure is achieved through appropriate:

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

During the last years, additional effort was 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.

(6) 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").

(7) Radiation protection culture

Internal and external workers are all committed to follow a base and periodic refresher training "nuclear safety culture" encompassing radiation protection. This training is the 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 Authority. 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.

Following Article 81.2 of the GRR-2001, the existing authorised release limits (gaseous and liquid releases) have been re-evaluated since 2002. The evaluation has been formally agreed by the Scientific Council of the FANC in December 2006.

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

	Gaseous releases	Liquid releases	**Total[5] maximum**
Tihange Site (3 units)	190µSv	80µSv	**210µSv**
Doel Site (4 units)	180µSv	230µSv	**370µSv**

Table 8 : Impact of Release Limits

[5] 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 in not in the same age category

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 new approach is 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 took 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.

	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 00	888	148 000
2008-2010 average	15 433	23	3,4	13	47 367
% of the limit	**0,70**	**0.15**	**0.003**	**1,46**	**32.0**
2011 values	5 993	12	335	12,6	39 490
2012 values	8 154	33	266	13,6	52 627
2013 values	4907	6	222	9	42451
2014 values	5629	9	251	7	44282
2015 values	4743	8	178	11	26016
2011-2015 average	6054	14	250,2	10,7	40973
2011-2015 % of the limit	**0,27**	**0,09**	**0,225**	**1,20**	**27,68**

	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
% of the limit	**0.001**	**0.42**	**0.004**	**0.24**	**47.17**
2011 values	36 476	106	132	10,1	55 182
2012 values	35 806	36	84,3	5,8	47 566
2013 values	29226	32	84	3,4	36609
2014 values	30136	32	89	2,4	36697
2015 values	56324	57	93	2,6	20413
2011-2015 average	37594	53	96,4	4,9	39293
2011-2015 % of the limit	**1,27**	**0,36**	**0,065**	**0,33**	**37,93**

Table 9 : 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 operator, 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 10 : Surveillance programme performed by the operator

II.J.4. **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 600 persons. More important, the maximum individual dose during the last years always has 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.

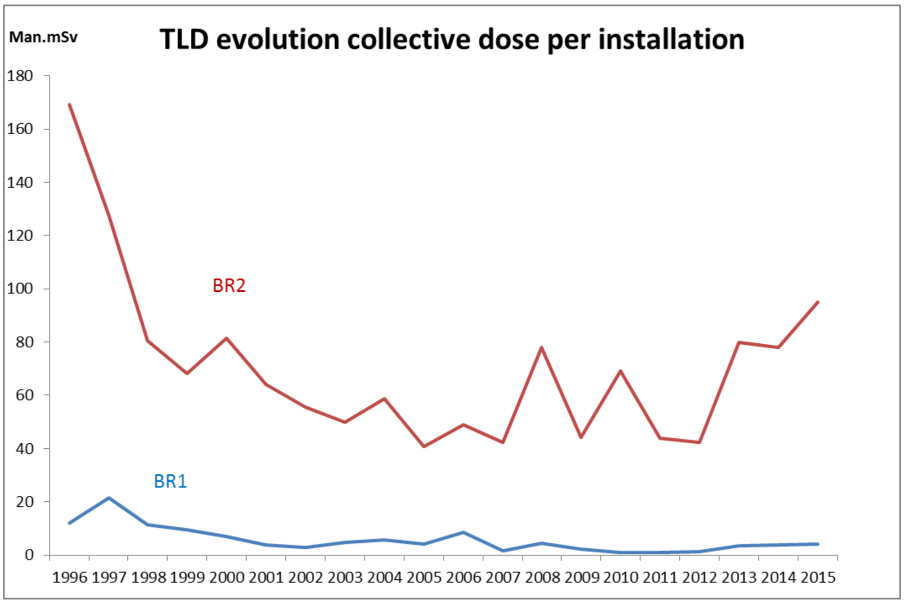

Figure 11 : Total Dose evolution per installation

Gaseous releases

The limits for radioactive gaseous releases were reviewed in 2002, following the implementation of the GRR-2001. The proposal was accepted by the FANC and the limits are integrated in the SCK•CEN Safety Analysis Report. 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: $\beta\gamma$ 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: α activity of aerosols, $\beta\gamma$ 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. The following comments could be made on the releases:

- From mid-2004 an increased release of I-131 was measured at the stack of BR1. This could possibly be an indicator for failed fuel cladding. Fuel channels with the highest thermal load were unloaded and the fuel was inspected. A number of failed fuel elements were discovered. All failed elements were replaced by new ones and since then releases of I-131 have fallen back to normal background levels.
- The years with higher level of iodine release of BR2 were due to periods with a higher failure rate of fuel plates. During the last years the number of fuel plate failures has become very low.
- The higher release in 2005 was due to a broken quartz irradiation ampoule in the hot cell containing fresh irradiated mercury. The released isotope was Hg-203
- 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 release of gaseous tritium is due to an old experimental device were 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 give still rise to a release of tritium.

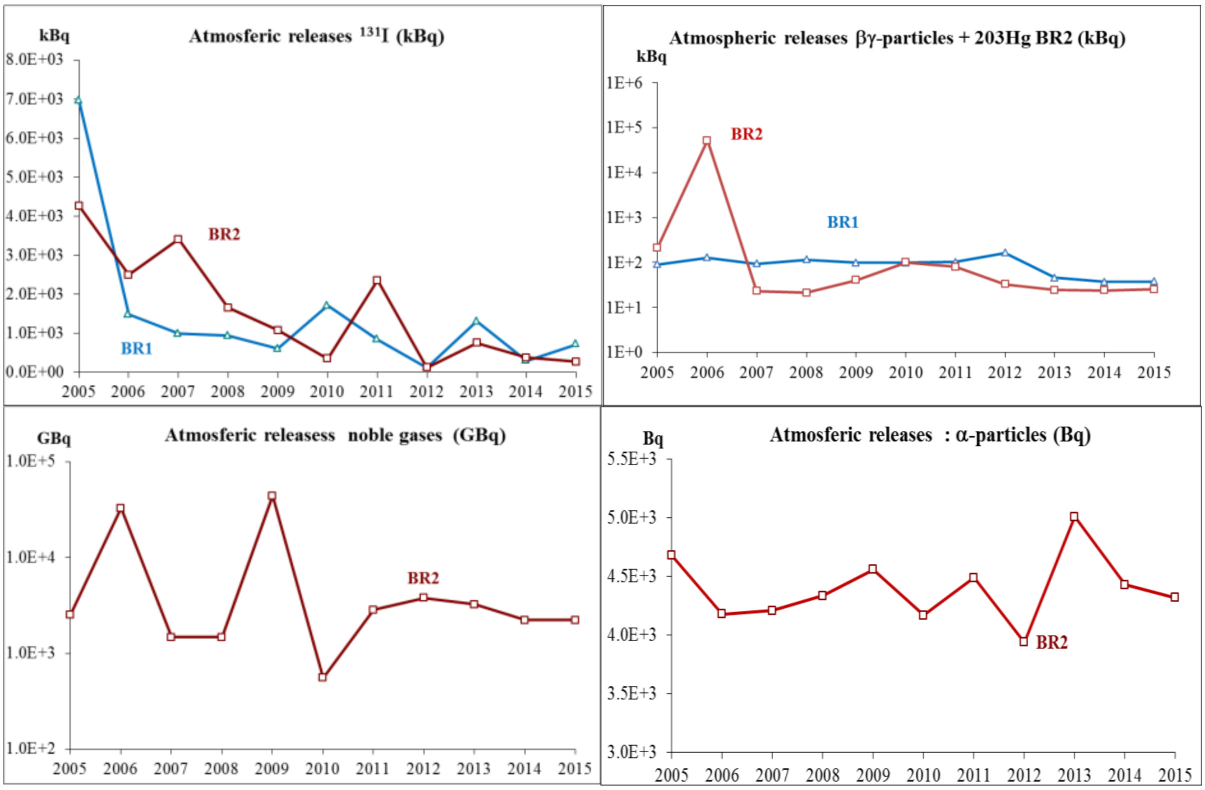

Figure 12 : Atmospheric Releases for SCK•CEN

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 α- 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 α- and β- 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.J.5. **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.K. 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.K.1. **Regulatory Framework**

The GRR-2001 in its Article 72 requires an emergency plan for the regulated installations potentially presenting a serious radiological risk. The Royal Decree of 17 October 2003 defines a nuclear and radiological emergency plan for the Belgian territory.

As already mentioned, this plan is presently under revision and the new version is expected by 2017.

II.K.2. **Implementation of Emergency Organisation in the Event of an Emergency**

a) Classification of Emergency

The Royal Decree of 17 October 2003 defines three levels for the notification of emergencies, which are in ascending order of seriousness N_1 to N_3, which the operator must use when warning the "Centre Gouvernemental de Coordination et de Crise - CGCCR" (i.e. the Governmental Centre for Co-ordination and Emergencies) which assembles under the authority of the Minister of Home Affairs. In addition, a fourth notification level ('reflex' level or N_R) has been considered to cope with events with fast kinetics. In case that 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 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 alarm level. In such case the governor of the province hosting the nuclear site is immediately notified in parallel to the warning message to the CGCCR. For each of these 4 notification levels (N_1 to N_3 + N_R) the notification criteria are defined in the Royal Decree of 17 October 2003. 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 'reflex' notification level, the activation criteria are based on predefined scenarios.

For example, the criterion associated with the N_1 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 (N_1 to N_3 + N_R) activates the federal emergency plan. In addition to these four levels, a "N_0" level is defined for notifying the Authorities in case of an operational anomaly. This last level does not activate the emergency plan.

All emergencies (N_1 to N_3 + N_R) have to be notified to the CGCCR. This permanently manned centre alerts the cells involved in the crisis management at the federal level (Emergency and Co-ordinating Committee, evaluation cell, measurement cell, information cell, socio-economical cell) and houses these cells during the crisis situation as well.

The "Emergency Director" of the Authorities transforms the notification level into an alarm level (U_1 to U_3), putting into action the corresponding phase of the National Emergency Plan. In the case of N_R, the U_R alarm level is automatically triggered and 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 CGCCR's cells are in place and operational, the UR alarm level will be converted to an appropriate alarm level 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 CGCCR is composed of the "Federal Co-ordination Committee" chaired by the Emergency Director of the Authorities, of the evaluation cell, of the measurement cell, of the information cell and the socio-economical cell, as indicated in the figure below.

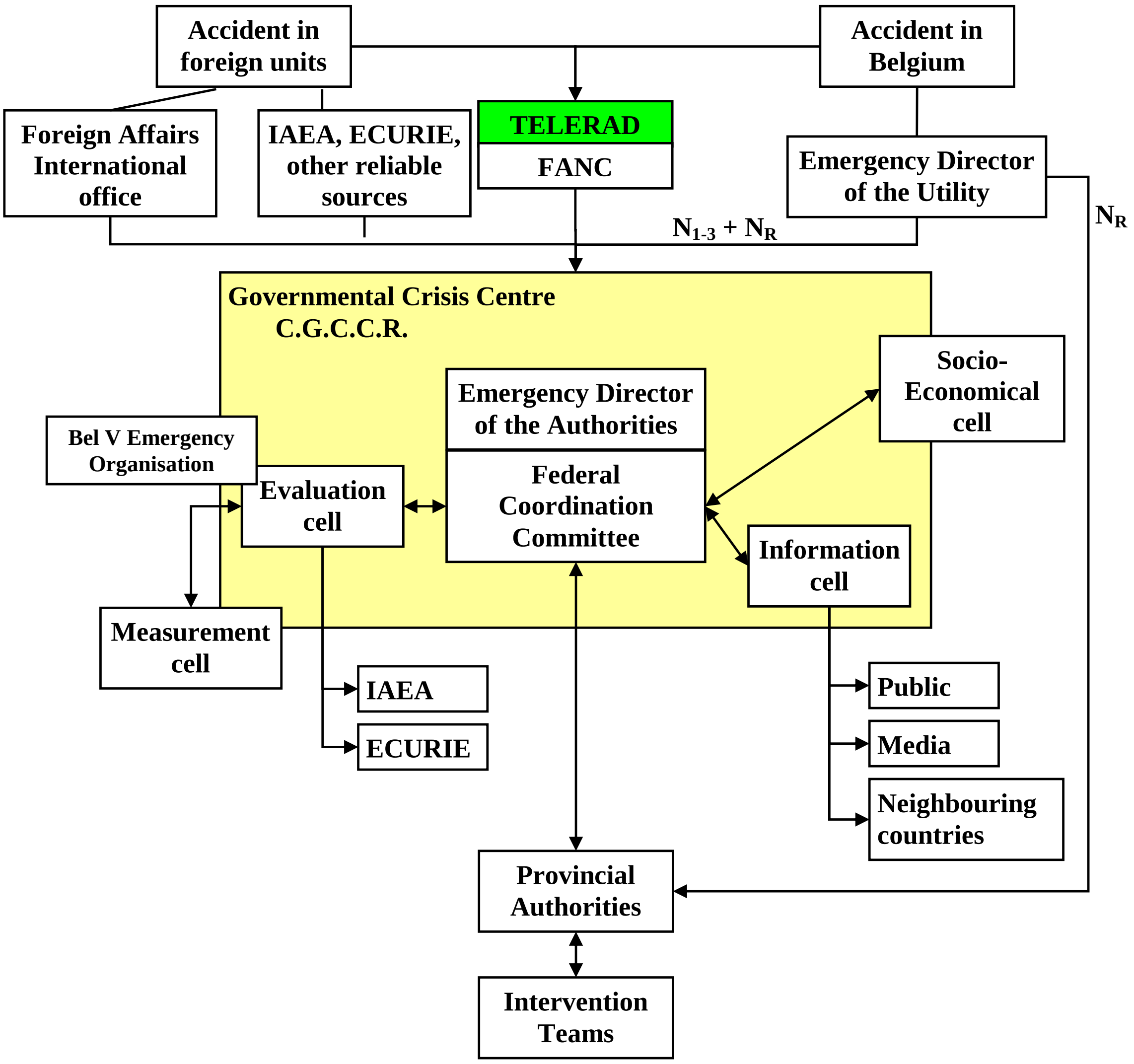

Figure 13 : EPP organisation for Belgium

In case of an accident abroad, the CGCCR, as National Warning Point (NWP), is informed by the Ministry of Foreign Affairs, the IAEA (through quick information exchange system EMERCON), 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 CGCCR 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 CGCCR. 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 221 stations for the measurement of the ambient dose rate in air, 7 stations for the measurement of iodine and β/γ in aerosols and 8 stations for the measurement of radiation in river water; 13 stations are complemented with a meteorological mast.

Next to the fixed measuring station network, 14 mobile measuring devices (GM detectors) are available to be positioned where needed e.g. to fill up gaps between fixed stations.

The figure below depicts the TELERAD network:

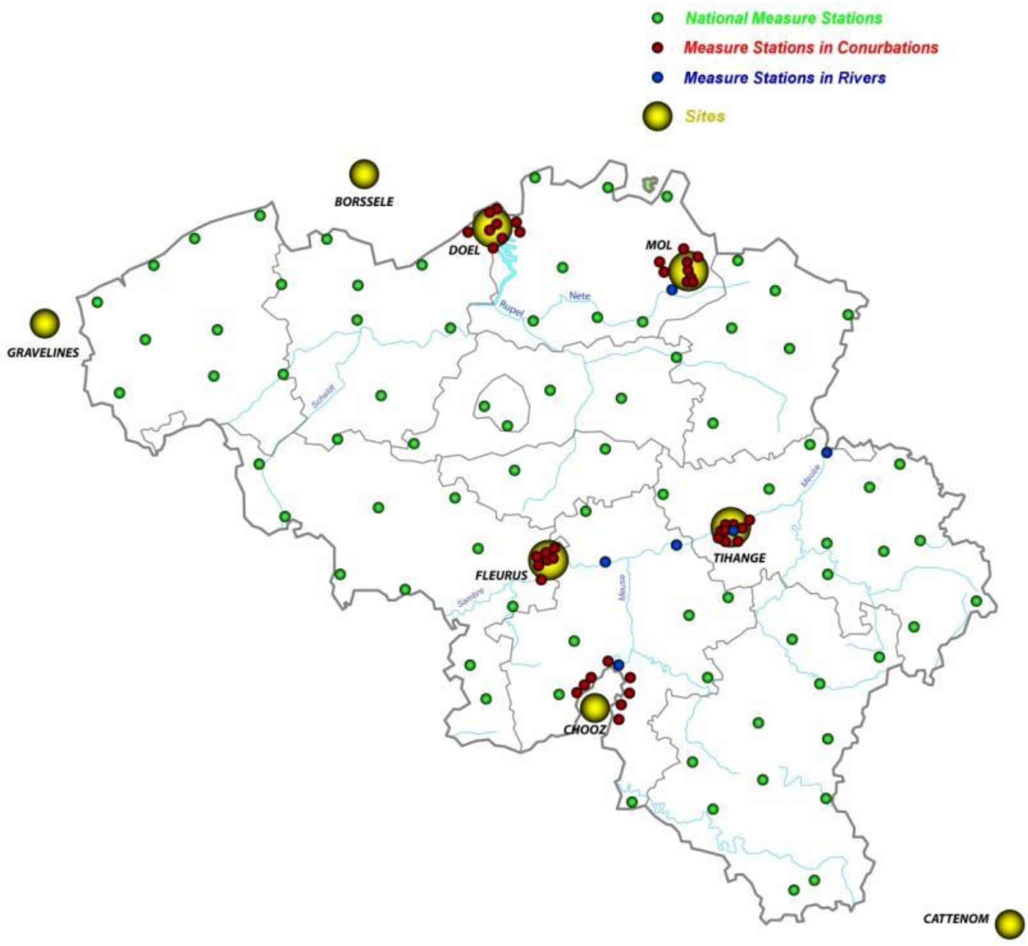

Figure 14 : TELERAD Network: location of the measuring stations

The Federal Co-ordination 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 Decision cell leans notably on the advices of the Evaluation and Socio-economical cells. 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 Federal Public Service of Foreign Affairs (for accidents abroad), the Department of Defence, 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 reference levels, issued by the FANC (24 November 2003). 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 socio-economical cell advises the Federal Co-ordination Committee on the feasibility and economic and social consequences of their decisions; it informs the Federal Co-ordination 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 CGCCR (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 17 October 2003 defines the emergency planning zones relative to the direct actions to protect the population (evacuation, sheltering, and iodine prophylaxis). These evacuation and sheltering zones have a 10 km radius around the nuclear plants; the stable iodine tablets pre-distribution zones extend to 20 km around the nuclear plants.

The intervention reference levels are set in the Decision of the FANC of 24 November 2003. They are 5 to 15 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 to 150 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 to 50 mSv thyroid equivalent dose for children less than 18 years and pregnant or breastfeeding women and 50 to 100 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 [6]. 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

[6] 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).

the latest version of the diffusion model [7], 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, simplified and user friendly tool 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 a continuously evolving issue on which is worked on a permanent basis. On the one hand 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 on the other hand.

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) and has been approved at the time of licensing. In complement, an "internal emergency plan" details the instructions for all the actors.

These emergency plans take into account the related post-TMI actions.

In case of accident the unit's "Centre Opérationnel de Tranche" (COT - Tihange) – "Bedrijfsfkamer" (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 CGCCR, and communicates with the Corporate crisis Organization.

The nuclear power plant conducts internal exercises several times a year, and the General Directions of Civil Safety and of Crisis Centre 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 in these exercises the various disciplines (fire brigade, medical help, police force, civil protection, measurement teams ...).

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 CGCCR, 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 N_2 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).

[7] 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).

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 CGCCR on the Belgian side and the CODISC ("Centre opérationnel de la Direction de la sécurité civile" which has now become 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 CGCCR 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.

As regards independent evaluation in the event of an emergency, Bel V which oversees the affected installation sends a representative to that site, a representative to the evaluation cell of the CGCCR, 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.

The following table gives an overview of some exercises (national and international) performed during the period 2013-2015 (only for the installations falling under the scope of the CNS):

Date	Site	Type	Objectives
25-28/06/2013	Cattenom (3 of 3)	International	Participation to the third phase (post-accident phase) of an international (involving the department of Loraine [FR], The GD of Luxemburg, the länder of Sarreland and Rhenanie-Palatinat [De] and the Wallon region [Be]) exercise in order to test the bilateral agreement on information exchanges at different levels. Scenario: LOCA. Mobilisation in real time. Use of fictive meteorological conditions. Duration of the exercise about 4 x 8 hours.

22/10/2013	NPP Doel	National	Global exercise directed by controllers, with the participation of some response organisations and deployment of field intervention teams Scenario: loss of cooling and recirculation systems during reactor shut down for maintenance leading to fuel damage. Atmospheric release through the stack. Mobilisation in real time. Use of fictive meteorological conditions. Duration of the exercise about 8 hours.
05/12/2013	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. Scenario: IS LOCA. Mobilisation in real time. Use of fictive meteorological conditions. Duration of the exercise about 6 hours.
29/04/2014	ConvEx 2a	International	Test of early notification procedures. Test for the submission of messages through the new USIE website.
26/05/2014	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. Scenario: fuel element not completely under water during downloading and blocked in this position. Mobilisation at a given time (pre-announced convening time). Use of real meteorological conditions. Duration of the exercise about 6 hours.
16/09/2014	NPP Chooz	International	Participation to a French exercise in order to test the bilateral agreement on information exchanges at different levels. Test of the HERCA/WENRA approach. Scenario: loos of cooling due to the clogging of water intake from the Meuse river subsequent to flooding. Mobilisation in real time. Use of fictive meteorological conditions. Duration of the exercise about 12 hours.

14/10/2014	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. Scenario: LOCA with containment failure. Mobilisation in real time. Use of fictive meteorological conditions. Duration of the exercise about 4 hours.
25/11/2014	ConvEx 2d	International	Test of early notification procedures. Test for the submission of messages through the new USIE website.
18/03/2015	ConvEx 2a	International	Test of early notification procedures. Test for the submission of messages through the new USIE website.
26/03/2015	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. Scenario: leak in a steam canalisation in the auxiliary building, together with a pipe break in a steam. Mobilisation at a given time (pre-announced convening time). Use of real meteorological conditions. Duration of the exercise about 6 hours.
25-27/08/2015	ConvEx 2b	International	Test of early notification procedures. Test for the submission of messages through the new USIE website.
26/11/2015	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. Use of the Crisis facilities of the FANC (back-up of the Belgian crisis centre due to the terrorism threat. Scenario: IS LOCA. Mobilisation in real time foreseen but not applied due to terrorism threat. Use of real meteorological conditions. Duration of the exercise about 6 hours.

Table 11 : Overview of EPP exercises for the period 2013-2015

d) Information of the Public

The GRR-2001 specifies in its Article 72 all the obligations regarding training and information of the public pursuant to the Directive 89/618/ Euratom.

During the accident itself, information is supplied to the media by the information cell of the CGCCR. 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.K.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 for 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 N1, N2, N3 and NR. The level NR, which means 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 by pass.

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. 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
>
> (v) impact on their own territory of the nuclear installation

II.L.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 (Antwerp) 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 demands 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. 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, 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 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 at the structure of the building due to high temperature exposure. In accordance with the fire department and Bel V, new equipment were bought and are 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 was assessed that an aircraft crash would result in unacceptable radiological consequences; taking into account the specificities of the buildings, that probability was found sufficiently low.

During the periodic safety review 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 changes. 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.

c) Stress Tests

Following the Fukushima Daiichi accident, the licensee was asked to conduct Stress Tests. Safety evaluation reports for the Doel and Tihange sites have been established by the licensee 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 revaluation of the seismic hazard by Electrabel (in collaboration with ROB and external experts for peered review) to confirm the adequateness of the seismic hazard considered for the seismic design of the NPPs.
- 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 15: 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 revaluation of the seismic hazard was ended in 2016 and is under evaluation by the Regulatory Body.

d) International Agreements

The necessity to inform the neighbouring countries when planning a nuclear installation is stipulated by Article 37 of the Euratom Treaty, and as a consequence is mandatory 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 is an obligation deriving from the Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.

II.L.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 due heavy rain combined with melting snow. Protection against this kind of flooding is under design
- 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 additional electrical power would be useful in case of a severely damaged installation.

b) Stress Tests

Following the Fukushima Daiichi accident, all "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 and SCK•CEN started to carry out the actions.

In relation to siting:

- A new Probabilistic seismic-hazard assessment study of the Mol-Dessel region was done by the Royal Observatory of Belgium. Following a graded approach, a return period of 1000 years (in place of 10000 years for NPP) was chosen. Despite the fact that the PGA level was substantially increased, enough margins were found for a large part of the Structures, Systems and Components important for safety. Although both reactors rely on natural convection cooling in emergency situation it was concluded that, for BR2, a seismic qualified electrical power system for the shroud cooling and the cooling of some experiments would be needed in case of a severely damaged installation. A seismic qualified monitoring system is also foreseen that gives information of the state of the installation after such a severe accident (see also II.B.2). A seismic qualification is on-going (action plan) for the remaining Structures, Systems and Components important for safety (mainly for the BR2 and BR1 reactors).
- Stress Tests confirmed that the risk of flooding is very limited. A deterministic approach was used to determine the potential impact on the installations, independently of the return period.
- Concerning bushfire, a 36m perimeter without trees has to be realized around the nuclear buildings.

- The risk of an airplane crash was also reassessed. Direct damage to the fuel or other vulnerable components is not expected. However, the crash of a large airplane could lead to a kerosene fire. Additional firefighting capabilities have been installed.

By the end of 2015 more than 60% of the actions was completed, about 15% is subject to review and Q&A following the transmission of documentation. Remaining actions are mostly long-term actions which either need a larger time span to carry out or which are carried as part of the periodic safety review of 2016.

Actions that were completed are, for instance:

- Structural reinforcements of specific buildings to improve their resistance against seismic events;
- Dedicated procedures for post-event recovery and long-term management of nuclear installations;
- Barriers with which excess water on-site following extreme precipitation is prevented from entering buildings;
- Increase of the tree-less perimeter around buildings reducing the risk and impact of forest fire.

Some long term actions which have been initiated are:

- Construction of a new building for diesel generators;
- Construction of a new network that provides water for firefighting;
- Improving the emergency electricity network.

II.M. 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.

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.

II.M.1. **NPPs**

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 are covered by the Euratom Directive on the Basic Safety Standards, which is mandatory for all member States of the European Union. 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 has been based on German rules. For the aircraft crash the bunkered structures have been designed to resist the impact of a civil airplane of about 90 tons at a speed of 85 m/s. 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 is a fortiori smaller, as exceeding the design criteria does not imply, with a probability equal to one, unacceptable radiological consequences.

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 the 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 a LTO-approach which is described in section I.C. 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.

We shall bear in mind that 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 after an accident, so as to collect possible leaks. 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).

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. Currently, recommendations from a review performed by an external company are being implemented in the PSA models. In parallel, internal fire and flooding PSAs are performed for representative units.

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 of course 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 stations easier and to increase their availability, the Belgian operator frequently apply 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 cards 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 former 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 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 are possibly amended to increase their efficiency and ease of use, or new procedures are written (for instance for the non-power states).

II.M.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. After 1965, the maximum thermal power has not exceeded 1 MWth. This allows working with the auxiliary ventilation only and avoids the accumulation of Wigner energy in the graphite. A power level of 4 MWth is still possible. The main ventilation was tested in 2012. However, operation at 4 MWth would require, after a certain time of irradiation, the thermal annealing of 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. After scram, both reactors can rely on passive cooling. Improvement of the availability of electrical power after a severe accident is foreseen. This power is needed for the cooling of the shroud of the vessel, the cooling of some experimental devices, instrumentation and measurements in order to have a correct overview of the installation and to make emergency interventions possible. For BR1 an additional protection tube is foreseen for one control rod, such that the reliability of the scram is increased in case of severe damage of the core due to an earthquake. For BR2, improvements are foreseen on the possibility to add water to the building and establish the natural convection.

II.N. 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.N.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 (T.S.) 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. T.S requirements and limitations are explicitly addressed in the maintenance procedures. Independent checks of the strict compliance with of T.S 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.2.a. 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 delivery 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 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 the operator, 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 operators crew (even-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 Technology 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.

On the corporate level, the sites receive technical support from the Asset Management and Strategy (AM&S) department. This department is, 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 (TE). The partnership translates into three levels of cooperation:

- Core assist: this is a strategic, permanent and structural partnership. In this framework, Electrabel entrusts activities to TE as its natural partner. Examples are safety and licensing (including studies, follow-up …), fuel management, regulatory watch, FSAR update management.
- Core support: this is a close cooperation that applies to projects for which similar quality levels cannot be obtained from other suppliers. Examples are general assistance in operations and management of nuclear installations, plant life management studies
- Valuable supplier: This is an operational competitive customer/supplier relationship for activities that are outsourced to an external supplier, but not necessarily to TE.

TE 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. TE 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... TE 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, TE maintains a high competency in conformity with the state of the art. In order to reach these goals, TE 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 Incident

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.

The use of INES is done via a convention between the Licensees, the FANC and Bel V. This convention stipulates in which circumstances and how INES is to be used. The licensee has to perform the 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. For events of level 1 or higher, the FANC publishes a short notice on its website. 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 will notify the IAEA.

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 Electrabel, Operating Experience is supported in all activities and at all levels of the organization. Operating Experience is part of the Electrabel's continuous improvement programme.

A policy for operating experience has been established at 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 plant 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.N.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 OLC's are defined in the licence.

These are for the BR1:

- 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.

These are for the BR2:

- 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 OLC's are detailed in the safety analysis report of the reactors. There is a significant difference between these two types of OLC's. 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

In 2008, the FANC published guidance about the treatment of modifications. The categorization and the treatment of modifications are described in section II.J.1 a) of the present report. Based on this guidance, 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. However, experimental devices are not considered as modifications. Special procedures exist for the approval of experiments.

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 discuss the return of experience and possible problems.

c) Reporting of Events

For reporting unusual events a convention with the authorities exists. 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. For BR2 all deviations from normal operation a non-conformity report (NCR) is issued and stored in a database. 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 NCR's 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.N.3. **Generation of Radioactive Waste**

See the Belgian national report in the frame of the Joint Convention (October 2014) : http://www.fanc.fgov.be/GED/00000000/3700/3778.pdf

II.N.4. **Temporary Storage of Used Fuel**

See Appendix 1, III.H and III.J and also the Belgian national report in the frame of the Joint Convention (October 2014).

III. Appendix 1 - Description of the Nuclear Installations: Power Plants

Not included in this version

IV. **Appendix 2 : Description of the BR1 and BR2 Research Reactors**

Not included in this version

V. 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).
AVN	Association Vinçotte Nuclear.
BDBE	Beyond Design Basis Earthquake
BS	Basic Standards.
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)
CSNI	Committee on the Safety of Nuclear Installations (NEA/OECD).
CW	Cooling water pipes
DBE	Design Basis Earthquake
ECURIE	European Community Urgent Radiological Information Exchange.
EDF	Electricité de France.
EDG	Emergency Diesel Groups
ENSREG	European Nuclear Safety Regulators Group
EU	European Union.
FANC	Federal Agency for Nuclear Control.
FBFC	Franco-Belge de Fabrication de Combustible (i.e. Franco-Belgian Company for Fuel Manufacturing).
FINAS	Fuel Incident Notification and Analysis System (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.
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).
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.
PSHA	Probabilistic seismic hazard analysis
PSA	Prabilistic 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
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.
TE	Tractebel Engineering.
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.
CNT	Centrale Nucléaire de Tihange (i.e. Tihange Nuclear Power Plant Site).

Table 12 : List of Acronyms

VI. Appendix 4 : List of the Web Sites of the Different Nuclear Actors in Belgium

VI.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)

VI.B. Licences, Architect-engineers, Research Centres

Electrabel:	http://corporate.engie-electrabel.be/	(site in French, Dutch and English)
Tractebel Engineering:	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:	http://www.nirond.be	(site in French, Dutch, English and German)
AIB-Vinçotte	https://www.vincotte.be/en_be/home/	(site in French, Dutch and English)

VI.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)

VI.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/

VII. Appendix 5 : Subjects examined during the Periodic (ten yearly) Safety Review

VII.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.

VII.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

VII.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

VII.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

VII.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 (eg. 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 Engineering). 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.

VIII. Appendix 6 – Belgian Action Plan as a result of the European Stress test process

Table 13: 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	closed
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	2016
Sensibilization campaign to seismic alertness		Continuation of efforts towards fostering awareness of potential seismic interaction inside facilities (scaffoldings,…)	closed
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	closed
Secondary effect of earthquake – Increase autonomy	Tihange 1	Assessment of earthquake impact on a fuel tank (fire, flood / resistance)	closed

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)	 closed closed
	Doel	Perimetric protection of relevant safety buildings (e.g. mobile barriers) Additional reinforcements of river embankments	closed closed
Enhanced operation management (procedures)	Tihange	Accelerated implementation of emergency preparedness strategy, organisation and procedures about flooding	closed
	Doel	Increase frequency of periodic inspections of embankments (height, erosion)	closed
	Doel	Implementation of procedures for mobile barriers	closed
Induced Internal hazards	Tihange	Internal hazards potentially induced by the flooding (fire, explosion) should be examined and additional measures should be taken where needed	closed
Emergency	Tihange	For the flooding risk, further	closed

preparedness and response		improvement of the emergency preparedness strategy 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, …)	closed

Enhanced protection Against extreme Weather	Tihange + Doel	Reassessments of sewer system capacity	closed
		Evaluation of protection against lightning (new standard NBN EN 62305)	ongoing
		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.	ongoing (Tihange), closed (Doel)
		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)	closed

Table 14: Design Issues

Loss of safety functions : Loss of Offsite Power

EDG autonomy	Tihange + Doel	Procedures to minimize the diesel consumption	closed
		Procedure to anticipate the make-up of oil for the diesels	closed
Offsite power Optimization	Tihange + Doel	Make a feasibility study to ensure a better separation of the high-voltage lines	ongoing
		Agreement with grid manager for ensuring the prioritization of the external supply to NPPs	closed

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	closed
Operational procedures	Tihange + Doel	To define a global strategy in the case of a « total SBO »	ongoing (Tihange), closed (Doel)

Shutdown states & midloop operation	Tihange 3	Feasibility study to ensure make up for the primary system in case of primary system open	closed
Instrumentation & Monitoring	Tihange + Doel	To add/check SFP level measurements	closed
	Tihange	Diesel generators for resupplying the I&C	closed
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.)	closed
		Account of the adverse conditions the NCM may be subject to (through technical characteristics and/or protection)	closed
SG protection	Tihange + Doel	To assess the potential overfilling or drying-out of the SGs due to the loss of ultimate compressed air	closed
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	closed

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)	ongoing (Tihange), closed (Doel)
Backup heat sink	Tihange	To integrate the use of the new groundwater of the site of Tihange in the supply of NCM equipment	closed
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.)	closed

Table 15: Severe Accident Management and Recovery

Severe accident management

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	closed
		Post-accident fixing of contamination and the treatment of potentially large volumes of contaminated water	closed

	Tihange	New site operation centre ("COS")		ongoing
SAM mitigation - Design	Tihange + Doel	Filtered containment venting system on each unit – from preliminary study to installation	2017	ongoing
	Tihange	Feasibility study: additional water injection into the reactor pit + additional containment spray		closed
H2 risk	Tihange + Doel	Assessment of the residual risk of hydrogen production and accumulation in spent fuel pool buildings		closed
SAM – R&D	Tihange + Doel	Follow-up of R&D activities related to the corium-concrete interaction & steam explosion issues	Continuous	closed
SAM – Improvement Guidelines	Doel	Improvement of SAMG: decision support tools, long term monitoring and exit guidelines,…		closed
SAM – Improvement Guidelines	Tihange + Doel	Improvement of SAMG: to include OEF Fukushima when WOG SAMG are revised		closed
SAM – Training	Tihange + Doel	Increase consistency between Tihange and Doel NPP on SAMG training for operators		closed
SAM – Control of releases	Tihange + Doel	Need to identify effective means to control pH inside containment		closed
SAM – Power supply	Tihange + Doel	Optimal battery load shedding strategy + calculation and decision tool		closed
Optimization of NCM	Tihange + Doel	Evaluation of the need to extend the NCM based on the analysis of the extensive damage mitigation guidelines ("EDMG")		closed

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