Environmental Impact Assessment Report

for the Facility for Treatment and Conditioning of Radioactive Waste with a High Volume Reduction Factor at Kozloduy Nuclear Power Plant

CHAPTER 2

ALTERNATIVES OF SITTING AND/OR ALTERNATIVES TO THE TECHNOLOGIES PROPOSED BY THE INVESTOR AND THE JUSTIFICATION OF THE CHOICE MADE

CONTENTS

2. ALTERNATIVES OF SITTING AND/OR ALTERNATIVES TO THE TECHNOLOGIES PROPOSED BY THE INVESTOR AND THE JUSTIFICATION OF THE CHOICE MADE

2.1 Alternative 0: Not realization of the investment project

The adopted in 2011 by the Council of Ministers "Strategy for management of spent nuclear fuel and radioactive waste" [11] includes the construction and commissioning of a facility for plasma treatment of RAW (PMF). Through implementation of this project a significant reduction of the volume of low and medium radioactive waste generated to the moment during operation of Units 1 to 6 is expected. This also applies for the radioactive waste that will be generated by the productive activity of Kozloduy NPP in subsequent years of operation of the plant and also during decommissioning of Units 1-6. Reduction of the volume of waste for disposal will lead to optimization of the costs of long term waste management.

By commissioning of the PMF, based on best available techniques and world experience in this respect, the current practical activities of Kozloduy NPP and SE "RAW" for treatment and conditioning of radioactive waste (RAW), generated during operation of the plant, will be expanded.

The PMF commissioning is important not only for the decommissioning activities of Units 1-4, but also for the overall operation of the Kozloduy NPP.

"Zero" alternative means that RAW is not treated in order to obtain a high coefficient of reduction in their volume, which can lead to lack of space for storage in an interim storage facility for conditioned radioactive waste.

Conclusions:

1. Alternative 0 is not acceptable, because it does not comply with the adopted by the Council of Ministers "Strategy for management of spent nuclear fuel and radioactive waste" [11].

2. Alternative 0 leads to higher costs for final disposal of radioactive waste.

3. The Alternative 0 is not acceptable for the implementation of continuous dismantling during decommissioning of KNPP Units 1 to 4.

2.2 Alternative 1: Other technological options for achieving high volume reduction factors

In the world practice, the only other technical option to reach a high volume reduction factor in comparison with the proposed treatment technology (PMF), is the implementation of a conventional incinerator. This can only be feasible if the untreated, pre-compacted and/or super-compacted waste is pre-treated and sorted out into burnable and not burnable material.

Detailed description of other technologies for achieving high volume reduction factor for RAW is presented in chapter 11, section 11.3. Information of the existing data in literature sources has been used. An economical and technical assessment of vitrification technologies in the frame of a feasibility study was executed for the development of the strategy for the RAW treatment from the NPP in South Korea [19]. The following technologies were assessed:

- Cold Crucible Melter heated by induction,
- Cold Crucible Melter heated by vertical electrodes,
- Quantum Catalytic Extraction Process, and
- Plasma Torch.

The study includes technical assessment based on the following parameters:

- Waste feeding (highest factor when all kinds of waste can be treated);
- Necessary replacement of materials during the melter life;
- Melter life;
- Output;
- Entrainment (retention) of Cs in waste;

And economic assessment with the main parameters:

- Capital and operation cost;
- Disposal costs based on the disposal volume, calculated with reasonable estimated volume reduction factors by considering the waste type and the treatment concept.

As result of the assessment it was concluded that the “Cold Crucible Melter” is the best option for treatment of combustible waste, and that the “Plasma Torch Melter” is the best option for non-combustible RAW. Only with the Plasma Torch Melter all kinds of RAW can be treated.

A concept for treatment and storage of all kinds of RAW from all operating NPP was realized in Switzerland. The responsible ZWILAG AG operates storage and conditioning facilities, including a plasma melting facility [20].

The comparison with the existing RAW processing facilities ZWILAG [58], CILVA [47] and the incineration facility WAK [59] in terms of effectiveness is shown in table 2.2-1.

The off-gas technology of the CILVA incineration facility is the same as the one planned for the PMF project at KNPP. ZWILAG, as the only existing facility for plasma treatment of RAW, and the incineration facility WAK have other technological concepts, but what they have in common is the combination of preliminary filtration or separation, scrubbers and HEPA filters. The annual mass flows are comparable (see also table 11.3.4-1 in chapter 11, section 11.3 of this report).

Table 2.2-1 Effectiveness of the off-gas cleaning systems compared to the PMF design characteristics

Facility	Incoming RAW (Bq/a)	Releases into air (Bq/a)	Decontamination coefficient*
ZWILAG	1E+12	5E+05	2E+06
CILVA	2E+11**	1E+05	2.E-06
WAK	1E+13	1E+06	1E+07

** Decontamination coefficient: activity of incoming RAW (Bq/a)/outgoing activity by emissions in the air (Bq/a).*
***Personal information from Mr. J. Deckers, BELGATOM. 07.03.2013.*

Other data for the operational experience of such facilities similar to the KNPP PMF, which have been reviewed in the design phase of KNPP PMF, are presented in chapter 11, section 11.3 (BAT).

This alternative is associated with considerable involvement by the operators, which is a prerequisite for greater risk of contamination spreading on the site area, and is associated with a significant loss of technological time for the sorting procedure.

Furthermore, the implementation of this alternative is associated with the reconstruction of another building within KNPP for the installation of the incineration facility or the construction of a new building for the incineration plant.

Conclusions:

1. In terms of risk to personnel from radiation exposure, conditioning technology with high volume reduction factor is recommended.

2. When selecting technology of incineration in a conventional incinerator, it is necessary to sort the waste by combustible and non-combustible, which is an additional risk for the personnel.

3. The implementation of an alternative other than the PMF is associated with the reconstruction of another building within KNPP for the installation of the incineration facility or the construction of a new building for the incineration plant.

2.3 Alternative 2: Plasma Melting Facility (PMF) for achieving high volume reduction factor (HVRF)

The proposed technology to be used for the PMF is based on Plasma melting, which is a high-energy technology able to treat a wide range of different types of waste.

The advantages of the proposed PMF are:

- All operational waste existing in KNPP can be treated in one central facility.
- Treatment of waste in the form, in which they are generated, with no need of pre-treatment, including sorting, depending on their physicochemical properties or radioactivity. The waste can be treated in a single process without additional sorting infrastructure.
- A volume reduction factor higher than 50 for not pre-compacted waste, higher than 10 for pre-compacted waste and higher than 2 for super compacted waste is guaranteed.
- The resulting waste form is free from any organic material and suitable for long term storage and disposal without further treatment.
- The waste drums are fed unopened, virtually eliminating the risk of direct radiation exposure and contamination to the personnel.
- The necessary operational flexibility to treat not only the listed waste, but also waste arising during the overall decommissioning process.

TECDOC-1527 [24] describes the application of thermal technologies for volume reduction and conditioning of radioactive waste.

In chapter 5 of this document, the plasma technology is assessed, and on page 47 it is written: “In contrast to radioactive waste incineration and other technologies which rely on the combustion of organic fuels, plasma torch enables thermal conversion to occur in a relatively small volume with high efficiency.” According to this document, the advantages are as follows:

- One single process can treat the waste as generated (i.e. no prior treatment is necessary). This reduces the infrastructure costs and reduces the radiation exposure to personnel from duplicative handling of the waste.
- The final waste form is robust, free of organic material, and suitable for long term storage and disposal.
- Volume reduction factors can range from 6:1 (typical ZWILAG results) for waste containing mostly metal and debris (including the waste containers) to 10:1 for treatment of mixed waste (typical RADON results) and to more than 100:1 for primary organic waste.
- Since the heat source is plasma instead of fossil fuels, there is less production of certain flue gases and the greenhouse gas CO2.

The following limitations are stated: expenses related to construction and operation, and the limited plant experience (only ZWILAG and RADON).

In terms of environmental issues it is written that an optimal off-gas treatment system has to achieve the regulatory limitation values for both nuclear and conventional emissions.

Regarding the existing PMF, ZWILAG and RADON, it is stated that: "the currently existing installations meet the highest environmental and regulatory standards of the day." It is also said that the energy consumption is higher in comparison to other methods, but, on the other hand, the product is suitable for disposal in a final storage.

The BAT assessment and definition [25] can be used for comparison with the PMF project in relation to the minimization of emissions of conventional air pollutants. In this case the general BAT criteria, and the criteria related to the requirements for off-gas treatment, can be taken into account. Officially, BAT is a tool used by the licensing authority to determine the BAT in specific cases. Chapter 4 describes in detail the techniques which are most relevant for determining BAT and permit conditions based on BAT.

The PMF technology proposed to be implemented at KNPP is in accordance with the following sections from chapter 4:

- Shredding of packaged and drummed waste (4.1.5.3);
- Pre-dusting stage by bag filters (4.4.2.1);
- Selection of filter bag materials; PTFE with excellent resistance for acid and alkali (4.4.2.4);
- Wet scrubbing, with a higher efficiency for acid gas absorption (4.4.3.1);
- Use of NaOH as alkaline reagent in wet scrubbing, higher reactivity for acid gases;
- Selective catalytic reduction (SCR) after dedusting and acid gas cleaning (4.4.4.1);
- Combination of dust removal + SCR, giving lower overall emissions of PCDD/F (4.4.5.3);
- Separate evaporation of wet scrubber effluent (4.5.15)

Based on the information from chapter 4, the BAT criteria are determined in chapter 5 [25].

- In the following part, all PMF related criteria are listed, mainly general criteria and criteria for the off-gas treatment process, as can be seen in table 2.3-1.

Table 2.3-1 List of PMF relevant BAT criteria

BAT criteria No.	Short description
3	Maintain all equipment in good working order
4	Quality controls over the waste input
5	Storage of waste input according to their risk assessment

9	Clear labeling of wastes stored in containers
10	Plan for prevention, detection and control of fire hazards
19	Use of optimized operating conditions
26	Optimization of installation energy efficiency and energy recovery (1)
32	Minimization of overall energy demand of the installation (2)
35	Overall flue gas treatment which guarantees operational emission levels listed in table 5.2 [3]
48a	Use of physical/chemical treatment of the scrubber effluents

(1) Remarks: (1) + (2) The SCR technology requires the reheating of the flue gas (4.4.4.1).
(2) See table 2.4-2 below.

The industrial experience with this proven technology, related to justification of the best available techniques (BAT) is described in detail and can be seen in chapter 11, section 11.3.

The alternative for construction of a PMF on the KNPP site for treatment and conditioning of radioactive waste with high volume reduction factor is justified based on the results from the emission values from PMF at KNPP, PMF at ZWILAG, the CILVA incineration facility, compared to the values from the Reference documents for BAT in this area [25], Directive 2010/75/EC [49], and considering the BAR requirements, indicated in section 11.3.

The tables below present the results from a comparison of the facilities with regard to the approved annual limits for emissions of β/γ radioactive aerosols and with regard to the emissions of conventional air pollutants.

Radiation emissions values

Table 2.3-2 presents a comparison of the approved annual limits for emissions of β/γ radioactive aerosols for the CILVA incineration facility and ZWILAG PMF with the guaranteed values for the KNPP PMF.

Table 2.3-2 Approved annual limited values for β/γ aerosols for CILVA incineration plant and ZWILAG Plasma Melting Facility in comparison with the guaranteed values of the Kozloduy PMF

Facility	Annual mass flow (t/a)	Approved annual emissions, Bq	Real annual emissions, Bq	Guaranteed annual emission
CILVA	ca. 200 (1)	1E+8 (1)	1E+5	
ZWILAG	200	1E+9 (2)	ca. 5E+5 (3)	
Kozloduy PMF	250			6.03E+6

(1) Evaluation from publication [47].
(2) Approved annual emission for all ZWILAG facilities, but the Plasma plant is the main emitter
(3) See [60].

– These facilities are comparable due to the annual input mass flow and the kind of input material: operational RAW from NPP;

- The guaranteed annual emission of the Kozloduy PMF is lower than the approved annual emissions of the indicated comparable facilities;
- The last parts of the off-gas treatment systems in these facilities are the same: HEPA filters and alkaline scrubber. Therefore, it can be expected that the real annual emissions from the Kozloduy PMF are lower than the guaranteed annual emissions.

Conventional air pollutant emission values

The conventional air pollutant emission values of this facility can be used for comparison because the PMF off-gas treatment is based also on the experience from the CILVA system.

In the following table 2.3-3 the emission limit values determined in Annex 4, section 3 of the EU Directive 2010/75/EU [26] and the emission levels of BREF for BAT during waste incineration [25] (chapter 5, table 5.2) are compared with the design values for the PMF [55].

The emission levels from the BREF are not defined as emission limit values, but as "operational performance levels that shall normally be anticipated from the application of BAT".

Table 2.3-3 Approved annual limit values for air pollutants from CILVA incineration plant and ZWILAG Plasma Melting Facility in comparison with the guaranteed values of the Kozloduy PMF

1	2	3	4	5	6	7
Pollutant	**BREF**	**Directive 2010/75/EU**	**ZWILAG approved**	**ZWILAG (annual average)**	**CILVA (annual average)**	**Kozloduy PMF [55]**
	Daily (1) average values mg/m³	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***	***Daily (1) average values mg/m³***
Total dust	1-5	10	10	2.58	0.56	< 1
CO	5-30		50	3.41	25	< 5
TOC	1-10	10	20		6	< 1
HCl	1-8	10	20	0.02	0.36	< 1
HF	<1	1	2	0	0.03	< 1
SO_2	1-40	50	50	7.72	17	< 5
NOx	40-100	200	80	15.01	133	<100
Heavy (2) metals						
∑ Cd, Tl	0.005-0.05	0.05	0.1		<0.02	0.005
Hg	0.001-0.02	0.05	0.1	0.01	<0.01	0.005
∑ Sb, As, Pb, Cr,	0.005-0.5	0.5	1*		<0.162	0.05

Cu, Mn, Ni, V, Sn						
Dioxines (3) and furans [ng/m³]	0.001-0.1	0.1	0.1		0.001	0.01

(1) *Conditions: 273 K, 101,3 kPa, 11% O_2, dry gas*
(2) *Average values over sample period minimum 30 min. –max. 8 hours*
(3) *Average values over sample period minimum 6 hours – max. 8 hours*
**Pb+Zn*

Effectiveness of the off-gas treatment systems

The off-gas treatment technology of the CILVA incineration facility is the same as the one planned for the KNPP PMF. ZWILAG, which is the only existing facility for plasma treatment of RAW, and the WAK incineration facility have other technological concepts, but what they have in common is the combination of preliminary filtration or separation, scrubbers and HEPA filters. Table 2.3-4 presents a comparison of the effectiveness of the off-gas treatment systems.

Table 2.3-4 Effectiveness of the off-gas treatment systems compared to the PMF design characteristics

Facility	Incoming RAW (Bq/a)	Releases into air (Bq/a)	Decontamination coefficient *	Comments
ZWILAG	1E+12	5E+05	2E+06	
CILVA	2E+11**	1E+05	2.E-06	
WAK	1E+13	1E+06	1E+07	
Kozloduy PMF	1.3E+11	6E+06	2.2E+04	Design

** Decontamination coefficient: activity of incoming RAW (Bq/a)/outgoing activity by emissions in the air (Bq/a).*
***Personal information from Mr. J. Deckers, BELGATOM. 07.03.2013.*

The results from this table show that the KNPP PMF emissions comply with the requirements of the BAT Referent documents in this area [25], Directive 2010/75/EU [49] and the Bulgarian normative document [48].

Conclusions:

1. The proposed "Plasma melting facility (PMF) with high volume reduction factor" complies with BAT in all aspects of RAW management and with the limit emissions of radionuclides and the limit emissions of conventional air pollutants.

2. The BAT recommendations for management of RAW generation and storage [28] have been used during EIAR elaboration to assess safety, PMF technical characteristics, and the environmental and socio-economic impacts.

3. Regarding the existing ZWILAG and CILVA PMF in operation, it can be said that the currently existing facilities comply with the highest ecological and normative standards of today.

4. The KNPP PMF emissions comply with the requirements of the BAT Referent documents in this area [25], Directive 2010/75/EU [49] and the Bulgarian normative document [48].

5. The selected technology complies with the IAEA requirements for such facilities for conditioning of RAW with high volume reduction factor.

6. PMF disadvantages are related to the construction and operation costs and the limited industrial experience (ZWILAG and CILVA only), as well as the high energy consumption as compared to the other methods. On the other hand, the product is suitable for final disposal.

2.4 Alternatives by location

In compliance with the regulatory requirements of Art. 38, 39 and 40 of the Regulation on the Safety of Radioactive Waste Management (adopted with CMD 198/3.08.2004, prom. SG 72/17.08.2004) the selection of a site for facilities for radioactive waste processing and storage shall be based upon evaluation of:

1. Inventory, characteristics and location of the existing waste, as well as the perspective for generation of radioactive waste;
2. Influence of the natural and technogenic factors on the safety of the facility;
3. Impact of the facility upon the environment;
4. Radiological impact of the facility on the population;
5. Specific characteristics of the site relevant to the migration and accumulation of radioactive substances;
6. Possibilities for application of protective measures to the population in case of accident in the facility;
7. Size of the special statutory areas and the emergency planning areas.

Site selection for a waste processing and storage facility shall be performed in such a way that the need of waste transportation is minimized.

No special requirements shall be put to the site for a waste processing and storage facility which meets both following conditions:

- The facility is located on the site of or in the vicinity of another facility, for which an operational license has been issued by BNRA, and
- The facility is intended to manage the waste generated in the same facility.

Since the facility will be implemented on the KNPP site, it will be part of the NPP territory, and thus the following issues have been resolved in compliance with the requirements of the Bulgarian legislation and without effect on the selection made:

- Transport access;
- Topographic characteristics of the area, soils characteristics, category of land use and climatic conditions;
- Establishing the use and ownership of land.

Out of the several alternatives by location that meet the regulatory requirements for the deployment of PMF, analyzed in the process of site selection, the alternative for PMF site within the AB-2 was strongly preferred.

The interconnections among all stages of RAW generation and management have been taken into account in the process of site selection. In other words, the optimal route has been sought for transportation of incoming RAW generated in the decommissioning process, so that the requirement under article 39 of the Regulation for safety during RAW management [5], according to which the choice of location for the facility site should minimize the need for RAW transportation, is fulfilled, and the requirements of article 38 of the same Regulation [5] are also fulfilled.

This alternative is not related to acquisition of new areas for the project implementation.

Conclusions:

1. The only reasonable sitting for the PMF is on the existing nuclear site of KNPP, as main radioactive waste producer.

2. The PMF, as a nuclear facility, must be located in a Controlled Area. Therefore, PMF is located in the AB-2 building, which is a Controlled Area.

3. The chosen location for the deployment of PMF fully complies with all regulatory requirements for site selection for deployment of a treatment facility for radioactive waste.

4. The site of AB-2 is appropriate because it was designed and licensed for the storage of radioactive waste, and it is already connected to existing drainage and ventilation systems of AB-2.

5. The selected location of the PMF in the existing AB-2 building is based on technical and economic considerations.

6. The choice of AB-2 is not associated with acquiring new land for the project.

2.5 Alternatives for RAW transportation

RAW transportation within Kozloduy NPP is not subject to special licensing and is part of the general licenses in force on the territory of plant. The scheme for transportation of unprocessed RAW for processing at PMF is shown on fig. 1.2.4.2-1 in chapter 1.

In regard to RAW transportation, a routing scheme has been developed, according to which PMF will accept waste from:

- Lime sector;
- RAW processing workshop;
- Size reduction and decontamination workshop;
- Transport corridor 1;
- Transport corridor 2.

The conditioned RAW slag, produced by plasma arch, in order to reduce the waste volume will be put in 200 l drums. These drums will be transferred to SD “Kozloduy RAW”, and will later be transferred to the National Repository for low and medium level RAW after cementation in RCCs.

<u>Conclusions</u>

1. The transportation of RAW is part of the license of Kozloduy NPP, and the scheme ensures minimal impact on the people and the environmental components.

2. The proposed two transport schemes for transporting of non-conditioned RAW to the PMF and transporting of conditioned RAW to SD “Kozloduy RAW” and the National Repository for low and medium level RAW match the current transport activities, which are well organized.

3. There is no need to change the transport schemes, and therefore it is not required to consider alternatives for transportation of non-conditioned RAW and RAW conditioned in the PMF.