NUCLEARELECTRICA

Translation from Romanian

ENDORSED,

Board of Directors
President
Alexandru SANDULESCU

NOTE
regarding the submission for the approval of the GMS of S.N. Nuclearelectrica S.A. of the „Long term development strategy of the Intermediary Dry Spent Fuel Storage Facility (DICA) in dry status and authorization in view of extending the lifespan of Units 1 and 2 consolidated with the CNCAN and of the Ministry of Environment and Climate Changes observations"

1. General aspects/brief history

The commissioning of Cernavoda NPP, Unit 1 (1996) and Unit 2 (2007) determined the need for performing and operating the Intermediary Dry Spent Fuel Storage Facility (DICA), according to regulations issued by the National Commission for the Control of Nuclear Activities (CNCAN), IAEA recommendations and international practice regarding spent fuel management, in order to intermediately store irradiated spent fuel from the reactor, after the temporary storage period (6 years) in the Spent Fuel Tank (SFT).
At international level was adopted, in September 1997, in Vienna, "The Joint Convention on the Safe Management of Spent Fuel and the Safe Management of Radioactive Waste", convention also ratified by Romania through Decree no. 192/1999. According to the Convention's provisions, "the spent fuel produced by nuclear plants shall be stored for a limited period in intermediate dry storage facilities".
At the national level, Law no. 111/1996 republished establishes the framework for the safe development, regulation, authorization and control of nuclear activities. By Order no. 844/2004 of the National Agency for Radioactive Waste, was approved the National strategy on average and long-term regarding spent nuclear fuel and radioactive waste management, including the final storage and the decommissioning nuclear and radiological installations. On this occasion, the authorization holders (SNN), are responsible for managing radioactive waste generated by their own activity and for drafting a preparation plan for decommissioning their own nuclear installation and submit it for the CNCAN approval. Also, CNCAN order no. 400 from 2005, establishes the applicable standards for the storage of solid radioactive waste. In regards to the legal obligations of SNN, according to the provisions of art. 24 of the G.O. no. 11/2003 regarding the safe management of radioactive waste, as subsequently amended by Law no. 378/2013, "**Holders of nuclear authorization are responsible** for the decommissioning of nuclear and/or radiological installations and **for managing radioactive waste resulted from the operation of nuclear and** radiological **installations** and for their decommissioning, **up to final storage**".

Requirements from the Maintenance and operation Authorizations of Units 1 and 2 from Cernavoda NPP provided by CNCAN (SNN CNE Cernavoda U1 – 01/2013 and U2 – 2/2013 Authorizations), provide, at art. 39, the fact that “radioactive waste shall be managed according to the provisions of the current regulations and CNCAN requirements” and, at art. 41, the commitment that “Cernavoda NPP shall perform and send to CNCAN, until June 30th, 2013, the strategy regarding the location and authorization plan for DICA”.

At this moment, the location and authorized surface for building DICA provided by the initial project ensured the fitting of a number of 27 MACSTOR 200-type modules, displayed on three lines. In the first line, according to the project, 7 modules are located and on lines 2 and 3, 10 modules each.

The intermediate solution for storing spent fuel at Cernavoda NPP is based on the dry storage system MACSTOR-type (Modular Air - Cooled STORage) developed by AECL and developed, for the first time, at Gentilly NPP, system based on the use of MACSTOR 200 storage module, which, in 2000, represented one of the most modern and advantageous storage solution.

The Decision of the General Meeting of Shareholders (GMS) no. 1/30.01.2000 approved the „Feasibility Study for the investment objective Intermediary Dry Spent Fuel Storage Facility (DICA) at CNE Cernavoda” („Feasibility Study for DICA Documentation code DI-08230-STP-SF01”) for the building of 27 MACSTOR 200 modules, with a total investment values of lei 181,766.200 thousand, by installments until 2040. In 2001 RAAN-CITON performed an update of the document code „DI-08230-STP-SF01 – Feasibility Study for DICA”, following the international tender regarding the acquisition of services and assets for DICA, with the new code DI-08230-SF01, targeting the building of 27 MACSTOR 200 modules, for storing spent fuel produced by two units, an operating cycle, resulting a total investment values of lei 232,745,829 thousand ($ 84,634,847), in installments until 2033. At the moment of drafting the „SNN Management plan”, by the Board of Directors (BoD of SNN) and approved by the GMS by Decision no. 19/24.07.2013, the DICA investment project was provided with the value of EUR 52 million, the equivalent of lei 232,745,829 thousand, the investment value according to the update of the Feasibility Study for DICA from 2001.

At the level of 2013, to respond to the request of art. 41 of the Maintenance and operation Authorizations of Units 1 and 2, mentioned above, was drafted the document Cernavoda NPP IR – 35370 – 006 (entitled “The long-term development strategy of the Intermediary Dry Spent Fuel Storage Facility in dried status and authorization in view of extending the lifespan of Units 1 and 2” - „Strategy DICA”). Subsequently to drafting the Notification Report previously mentioned**,** was identified the need to review the DICA Strategy for responding to the requirements for intermediate storage of used fuel from Units 1 and 2, as well as from Units 3 and 4, following the MMSC request (Ministry of Environment and Climate Changes) to approach, under a unitary vision, for the subject matter, the entire location from Cernavoda. Therefore, in October 2014, revision 3 of the Notification Report was issued, entitled “Long term development strategy for the Intermediary Dry Spent Fuel Storage Facility in dried status and authorization in view of extending the lifespan of Units 1 and 2 in compliance with CNCAN and MMSC observations” („The revised DICA strategy”)**.** The solution on which the new approach is based is that of improving the efficiency of the use of the DICA location by changing the current project, providing the storage of spent fuel in MACSTOR 200 modules, in the sense of transferring to the MACSTOR 400 modules version (with a double storage capacity), developed following the collaboration between AECL (Atomic Energy of Canada Limited), Korea Hydro& Nuclear Co. (KHNP) and Nuclear Environment Technology Institute (NETEC).

The revised DICA strategy IR – 35370 – 006 rev. 3, providing the trasnfer to the version with MACSTOR 400 modules, was submitted to approval and received the CTES approval no. 26/29.10.2014. Subsequently, as per the SNN Note no. 13188/12.11.2014, the revised DICA strategy was submitted to the approval of SNN BoD.

By Decision no. 164/13.11.2014, the SNN BoD decided that the document „Update of the Feasibility Study for DICA” should be reviewed according to the new approach for transfering to the version with MACSTOR 400 modules and postponed the authorization of the revised DICA strategy, following for it to be submitted by the SNN BoD (and, subsequently, forwarded for the GMS approval) together with the approval of the DICA Feasibility Study update. Following those presented above, it was necessary for the document „DICA Feasibility Study update" to be reviewed according to the revised DICA strategy. On this occasion, was considered the storage capacity existent at DICA (7 MACSTOR 200 modules) and the fact that the construction of MACSTOR 400 modules shall need additional approvals (CNCAN authorization, environment approval) with extended periods for obtaining them, proposing to continue the building of yet another two modules (8 and 9) MACSTOR 200-type, providing the necessary time for approving the MACSTOR 400 project and then for continuing the building up to module no. 30 with MACSTOR 400-type modules.

The review of the document „DICA Feasibility Study Update" was performed by CITON (document code DI-08230-SF01 Rev 1: "DICA Feasibility Study Update rev. 1").

In order to identify the most feasible technical-economical scenario by which the DICA objective may be extended in order to accommodate the used fuel quantity resulted from the operation of Units 1 and 2, two operating cycles, the hereby study analyzes two extension scenarios for the existent DICA site and namely:

Scenario I

Scenario I, estimating the building, in addition to the 7 MACSTOR 200-type modules already existing, operational in 2016, for two more MACSTOR 200-type modules and also, starting with module 10, to continue to build 21 MACSTOR 400-type modules.

Scenario II

Scenario II, estimating the building, in addition to the 7 MACSTOR 200-type modules already existing, operational in 2016, for 44 more MACSTOR 200-type modules and to continue to build this type of modules up to module 51.

Technical comparative analysis between the two scenarios

From table 1, one can see that between the two types of MACSTOR 200 and MACSTOR 400 modules, there are no major differences (only the width differs) leading to a similar operation method by compatibility with already existing equipment.
It must be mentioned that the dimensions and characteristics of module MACSTOR 400 do not imply major changes, during the transition period, in the current display of module lines within DICA.

Tabble 1

Parameter	MACSTOR 200	MACSTOR 400
Length (m)	21,64	21,94
Width (m)	8,13	12,95
Height (m)	7,50	7,60
No. of cylinders per module	20	40
No. of fuel bundles to be stored per module	12.000	24.000
No. of baskets to be stored per module	200	400
Heat discharge per module	73KW(analyzed at 78 KW)	149.9 KW(analyzed at 146,7 KW)

Table 2 shows the most important technical aspects differentiating the two scenarios starting from the storage requirement of an identical number of fuel bundles.

Table 2

Parameter	Scenario I	Scenario II
Total number of stored bundles	612.000	612.000
No. of new necessary portal	4	6

cranes		
Drawing manholes/ cable connection	6 /23	8/30
Water collection manholes and valve manholes	22	21
New roads between modules	3	5
Road surfaces and new platforms (m^2)	4.500	6.700
Physical protection new fence (m)	330	375
Sitesewage network (m)	616	860
Rainwater sewage network surrounding to the modules (m)	2.060	3.120
Rainwater sewage ditch at the slope base	655	710

Comparative economical analysis between the two scenarios

The economic analysis presents a comparison between the costs associated to each scenario, as follows:

Scenario I

In this version, the DICA site consists in, in addition to the existing 7 MACSTOR 200 modules, two more MACSTOR 200 modules and 21 MACSTOR 400 type modules to be constructed, making a total number of 30 modules, displayed on 4 lines.
The table below presents the total costs for Scenario I:

Name of costs chapters	Value (without VAT)		VAT thousand lei	Value (including VAT)	
	Thousand lei	Thousand euro		Thousand lei	Thousand euro
Total General:	604.567,54	134.348,34	145.096,21	749.663,75	166.591,94
din care : C+M	300.043,80	66.676,40	72.010,51	372.054,31	82.678,74

Scenario II

In this version DICA site consists in, in addition to the existing 7 MACSTOR 200-type modules, 44 more MACSTOR 200-type modules to be built, up to a total of 51 modules displayed on 6 lines.
The table below presents the total costs for Scenario II:

Name of costs chapters	Value (without VAT)		VAT thousand lei	Value (including VAT)	
	Thousand lei	Thousand euro		Thousand lei	Thousand euro
Total General:	710.651,36	157.922,52	170.556,32	881.207,68	195.823,93
din care : C+M	389.889,97	86.642,22	95.573,59	483.463,56	107.436,35

Note: costs were established in lei thousand at the exchange rate of lei 4.50 /EUR.

From the technical point of view, "DICA Feasibility Study Update rev 1", complies with the quality requirements established by the current laws and regulations, and from the economic point of view, evaluations were performed based on the experience from building the first 7 MACSTOR 200 modules, considering the price evolution and inflation. The site in both scenarios is extended towards the Reactor Building of Unit 5, where lime stone is high enough in order to allow a safe foundation for the modules.

“DICA Feasibility Study Update rev. 1” received the CTES approval no. 3 on 10.02.2016.

2. Conclusions of the technical-economical analysis

From the technical point of view, of labor volume, construction time, usage of land and material consumption, Scenario I has clear advantages, detailed as such in the “Feasibility Study Update rev. 1” by the Study author, RATEN- CITON. DICA extension solution on which Scenario I is based is the one for increasing the efficiency of the use of the DICA site, leading to a significant increase of storage density on the surface unit, therefore allowing: to double the storage capacity on the same surface and with the resulted space, allowing the continuous building of the modules necessary for storing the resulted fuel from Units 3 and 4 operation.

From the economical point of view, Scenario I, with a total investment values of lei 604,567.54 thousand without VAT (EUR 134,348.34 thousand), is more advantageous and shows total costs without VAT, decreased by lei 106,083.82 thousand (EUR 23,574.18 thousand) compared to Scenario II.

In conclusion, according to the performed technical-economical analysis, the “Feasibility Study update rev. 1” identified Scenario I as the most advantageous from the technical and economical point of view, therefore, proposes this scenario for the investment.

3. Proposals

Considering the above mentioned as well as the following:

(i) By the Decision of the GMS no. 1/30.01.2000 was approved the „Feasibility Study for the investment objective Intermediary Dry Spent Fuel Storage Facility (DICA) at Cernavoda NPP”, respectively the investment project on the MACSTOR 200 solution;

(ii) The fact that, according to the provisions of art. 13 paragraph 2 letter h), the OGMS has the competence of approving the company’s development strategy and policies;

(iii) The fact that „The long term development strategy of the Intermediary Dry Spent Fuel Storage Facility in dry status and authorization in view of extending the lifespan of Units 1 and 2 consolidated with the CNCAN and of the Ministry of Environment and Climate Changes observations**”** involves the strategic approach of SNN regarding the compliance with its legal national and international obligations and with the conditions requested by the National Commission for the Control Nuclear Activities Control (CNCAN) in the plant’s operation permit, regarding the obligation of providing the compliant capacities and conditions of dry storage for the spent fuel in DICA;

(iv) The fact that the BoD decision of SNN no. 72 / 08.06.2016 endorsed at art. 1 „The long-term development strategy of the Intermediary Dry Spent Fuel Storage Facility in dried status and authorization for the extension of lifespan for Units 1 and 2 consolidated with the CNCAN and MMSC observations**” („DICA revised strategy”),** document Cernavoda NPP code IR-35370-006 rev.3 (approved in CTES with approval no. 26/29.10.2014 and approved by CNCAN with address no. 24376/11.12.2014, registered at Cernavoda NPP with no. CNCAN_CNE14-247/12.12.2014) and art. 2 endorsed the DICA updated investment project based on the document „DICA Feasibility Study update rev. 1” drafted by RATEN - CITON (approved in CTES with approval no. 3/10.02.2016), respectively the implementation, at the SNN level, of Scenario I recommended within the previously mentioned work, according to those presented in the SNN Note no. 6679 / 27.05.2016 (implementing the version envisioning the building, in addition to the existing 7 MACSTOR 200-type modules, operational in 2016, of two more MACSTOR 200-type modules and continue to build, starting with module 10, 21 MACSTOR 400-type modules), scenario requesting an investment amounting to lei 604,567.54 thousand without VAT being extended on a period of 32 years.

We submit to the approval of the SNN OGMS the following:

"The long term development strategy of the Intermediary Dry Spent Fuel Storage Facility (DICA) and the authorization in view of the life time extension of Cernavoda NPP Units 1 and 2 in compliance with the observations of CNCAN and the Ministry of Environment and Climate Change".

Daniela Lulache	**Mihai Darie**
General Manager	**Financial Manager**

Annexes:

The executive brief of the „DICA Feasibility Study updates rev. 1"

__Translation from Romanian__

The executive summary for the "Update of Feasibility Study for the Intermediary Storage Facility for Spent Fuel (ISFSF) rev. 1"

1. Specific issues

In accordance with the CANDU 600 standard project, the spent fuel burned in the reactor of nuclear units is stored temporarily under water, in the Main Tank for Spent Fuel Storage (TSF), dimensioned so as to ensure a storage capacity deemed to be sufficient for 10 years of operation of the reactor. While maintaining a capacity factor of 80%, the average lifespan of CANDU 600 reactor is about 30 years before the refurbishment.

Law 111/1996 on safe deployment of nuclear activities also stipulates the responsibilities incumbent to the permits' holders who must manage the spent nuclear fuel and radioactive waste in order to dispose them definitively throughout the useful life of nuclear and radiological facilities including during their decommissioning.

In this context, it was imperative for Cernavodă NPP to find a solution for the storage of spent nuclear fuel after its removal from the TSF. As a solution, the project AECL - "Monolithic Concrete Way" MACSTOR type was selected. This project is specific to the dry intermediate storage of CANDU fuel. This storage system was first used at Gentilly NPP in Canada, based on the use of MACSTOR 200 storage module, which, in 2000, was one of the most modern and convenient storage solutions.

2. Description of MACSTOR 200 and MACSTOR 400

The basic principle of dry storage systems consists of storing the spent fuel for a period of 50 years under secure operating conditions for the operators, population and environment by providing barriers to the environment, removal of residual heat of the fuel stored and ensuring appropriate radiological protection.

The Intermediary Storage Facility for Spent Fuel (ISFSF), in which the intermediate spent fuel is stored, has a modular design, allowing its gradual construction, as the spent fuel temporarily (at least 6 years) stored in the TSF of Units 1 and 2 can be transferred in ISFSF.

Currently, the ISFSF objective is authorized by CNCAN, and provides the placement of 27 MACSTOR 200 modules, on 3 rows, each module housing 20 storage cylinders with 10 baskets per cylinder, with a total capacity of 12,000 bundles per module, amounting to a total storage capacity of 324,000 bundles.

This capacity allows the intermediate storage of the spent fuel originated from Units 1 and 2 during a cycle of life (without upgrading). By extending the operation of Units 1 and 2 with another operating cycle [Ref: 35370-006 IR rev.3] a revision of the existing project is required for enlarging the ISFSF site.

Currently, 7 MACSTOR 200 storage modules are built on the ISFSF site.

Each 200 MACSTOR module consists of a paralellipipedic construction with reinforced concrete monolithic structure, which is 21.64 m long, 8.13 m wide and 7.51 m tall including 20 metal enclosures – storage cylinders vertically placed, 10 cylinders on two parallel rows. In each of these cylinders 10

baskets filled with 60-spent fuel bundles are stacked. Thus, each MACSTOR 200 module stores 12,000 spent fuel bundles.
MACSTOR 400 module is all a monolithic concrete structure, 21.94 m long, 7.60 m high and 12.95 m wide, which houses 40 storage cylinders vertically placed on 4 rows.

From the constructive point of view, MACSTOR 400 module is an upgraded version of MACSTOR 200 storage module, with a double total storage capacity (24,000 bundles) compared to the one of MACSTOR 200 modules. From the constructive point of view, MACSTOR 400 module storage cylinders are similar to the MACSTOR 200 modules, having instead reinforced motherboard and reinforcing ribs.

3. Necessity and opportunity of investment

The spent fuel is unloaded from the reactor into the spent fuel tank, then transferred into the reception tank and finally the fuel bundles are transferred to the storage tank where they are temporarily stored (at least 6 years). After this period, the spent fuel is loaded into baskets and transferred to the spent fuel storage facility ISFSF, where it will be stored for another 50 years.

The real intermediary capacity of spent fuel storage tanks is approximately 36,450 bundles for Unit 1 and 34,300 bundles for Unit 2, since:

- For nuclear safety reasons, a permanent sufficient spare capacity must be provided to transfer all the existing 4,560 fuel bundles into the reactor;
- At least 4 stacking locations (storage room equivalent to 1,728 bundles) must be reserved as a buffer zone for handling pallets during the stacking procedures;
- Necessary room for loading the bundles into the spent fuel storage basket representing 2 rows of stacks on the width of the tank which means about 14 stacks.

In this context, the storage capacity of the spent fuel tank (SFT) being about 48,000 bundles, considered sufficient for 10 years of operation of the reactor at a capacity factor of 80%, it was absolutely necessary to find a solution for the intermediary storage to ensure the storage of the spent fuel in a different location than the SFT tank.

Therefore, the intermediary dry storage solution MACTROR 200 has been chosen.

3.1. Intermediary storage capacity required

Determination of dry intermediary storage capacity is based on the technical considerations regarding the number of fuel bundles that are burned annually in each reactor. CANDU reactors have a life cycle estimated at 210,000 EFPH (Effective Full Power Hours - total hours of operation at 100% power), limited by the condition of pressure tubes in the active area. Quantification of operation made per calendar years depends on the capacity factor achieved in operation. For a medium performance plant an average capacity factor of 80% per year, namely 7,000 EFPH/year with an average fuel consumption of 4,800 bundles per year is considered. By increasing the capacity factor, the number of spent bundles increases, too, and the number of calendar years of operation correspondingly decreases.

The total number of bundles of spent fuel resulting from the operation of a CANDU 600 reactor during a life cycle of 210,000 EFPH at a capacity factor of 80% (equivalent to 30 years of operation) is:

$$30_{\text{years}} \text{ X } 4.672_{\text{bundles/year}} + 4.560_{\text{bundles}} - 1.600_{\text{bundles}} = 143.120_{\text{bundles}}$$

To validate the above considerations is stated that on 01.04.2014 the total number of bundles of spent fuel resulting from Units 1 and 2 amounted to a total of 122,845, as follows:

- 54,600 bundles already stored in ISFSF
- 35,602 U1 bundles stored in SFT U1
- 32,645 bundles stored in SFT U2

Given the time during which the nuclear fuel was generated, namely 17 years at U1, with a capacity factor of 90,48% and 6 years at U2, with a capacity factor of 94,15%, we notice that the average annual production rate for spent fuel is:

- For U1 -> 90,202 fuel bundles: 17 operational years = 5.306 bundles/year
- For U2 -> 32,643 fuel bundles: 6 operational years = 5.440 bundles/year

By operation of a unit at a capacity average factor of approximately 90% it is expected that the life cycle of 210,000 EFPH corresponds to 26 calendar years compared to 30 years that would have been with a factor of up to 80%. It follows a 5,336 average number of bundles of fuel burned per year. Therefore, the amount of spent fuel resulting in the end of a 26-year lifecycle at a capacity factor of about 90% will be 143,296 bundles.

Further, the amount of 5,336 spent fuel bundles/year with a 26-year lifetime will be considered. Under these conditions, the total intermediary storage capacity of the spent fuel required if the two operated units -U1 and U2 – operate (each of them) a lifecycle will be:

Case 1: **Units U1 and U2 in operation – one operation cycle:**

2_{units} X (26_{years} X $5.336_{\text{bundles/year}}$) + 2_{units} X $1_{\text{unloading}}$ X (380_{ducts} X 12 $_{\text{bundles/duct}}$) = 286.592 bundles

If the lifecycle of units U1 and U2 is extended with an additional cycle of operation and the average rate of production amounts to 5,336 spent fuel bundles/year, we notice that a ISFSF storage room has to be provided for:

Case 2: **UnitsU1 and U2 in operation – two operation cycles:**

2_{units} X (52_{years} X $5.336_{\text{bundles/year}}$) + 2_{units} X $2_{\text{unloadings}}$ X (380_{ducts} X 12 $_{\text{bundles/duct}}$) = 573.184 bundles

Currently, the existing project for ISFSF building involves the construction of 27 MACSTOR 200 modules, which total storage capacity amounts to $27_{\text{Macstor200modules}}$ X $12{,}000_{\text{bundles/module}}$ = 324,000 bundles. This capacity provides the only housing of the fuel produced in Case 1 above.

Currently, the ISFSF storage facility has the first row completed with MACSTOR 200 modules that provide a total storage capacity of 84,000 bundles.

For the reasons set out above it is clear the need to extend the dry storage capacity of the spent nuclear fuel compared to the initial version of the project provided with 27 MACSTOR 200 modules.

4. Technical and Economic Scenarios

In order to identify the most feasible technical and economic scenario by which the ISFSF facility can be extended for housing the amount of spent fuel resulting from the operation of Units 1 and 2 with two operating cycles, two scenarios for ISFSF site extension are considered, namely:

First Scenario

In this first scenario, in addition to the existing seven 200 MACSTOR modules, which were operational in 2016, two MACSTOR 200 modules are expected to be built. Starting with module no. 10, twenty-one 400 MACSTOR are also expected to be built.

Second Scenario

In this second scenario, in addition to the existing seven 200 MACSTOR modules, which were operational in 2016, forty-four MACSTOR 200 modules are expected to be built up to module no. 51.

4.1. Analysis of first scenario

This scenario is based on the efficient use of the allocated ISFSF site by modifying the current project (which provides the storage of spent fuel in MACSTOR 200 modules) and starting using MACSTOR 400 modules developed by AECL, KHMP and NETEC.

In this version the ISFSF site contains nine MACSTOR 200 modules and twenty-one MACSTOR 400 modules placed on 4 parallel rows. Basically by implementation of MACSTOR 400 module (which is much more compact and has a double storage capacity) starting with module no. 10 the storage density per unit area would be significantly increased by making best use of the land allocated. MACSTOR 400 module is more compact. Although it is based on MACSTOR 200 module, its storage capacity is doubled (24,000 bundles) compared to MACSTOR 200 module.

Table 1

Parameter	MACSTOR 200	MACSTOR 400
Length (m)	21.64	21.94
Width (m)	8.13	12.95
Height (m)	7.50	7.60
Number of cylinders per module	20	40
Number of bundles that can be stored per module	12,000	24,000
Number of baskets that can be stored per module	200	400
Heat dissipated by a module	73KW(analysed at 78 KW)	149.9 KW(analysed at 146.7 KW)

We can notice in Table 1 that between the two types of models MACSTOR 200 and MACSTOR 400 there are no major structural differences (width varies only) leading to an operating mode similar due to the compatibility with the existing equipment.
We also notice that the dimensions and characteristics of MACSTOR 400 module allow the transition to be done without major changes in the current arrangements of modules rows within ISFSF.
Consequently, to ensure storage of spent fuel bundles resulted during the two cycles of operation of Units 1 and 2, the need to build a number of twenty-one MACSTOR 400 modules was identified as follows:

No. of MACSTOR 400 modules = $(573.184_{\text{bundlesU1/U2}} - 9_{\text{MACSTOR200 modules}} \times 12.000_{\text{bundles/Module}})/24.000_{\text{bundles/MACSTOR 400 module}}$ = 19.38 MACTOR 400 modules

To further ensure a storage room reserve this figure is rounded off to twenty-one MACSTOR 400 modules, thus, additional room for 38,816 bundles storage is provided. It follows that to ensure the storage of spent fuel bundles resulting from the operation of Units 1 and 2 with 2 cycles of operation, in the first scenario thirty MACSTOR modules (a number of nine MACSTOR 200 modules and twenty-one MACSTOR 400 modules) will be necessary. To achieve this scenario, 1,020 storage cylinders and 10,200 storage baskets for the spent fuel are necessary, the maximum storage capacity being 612,000 bundles.

Given that the current authorised location ensures the construction of only 3 rows of modules, it follows that the construction of the fourth row of modules in the first Scenario requires an increase in the site area. The calculations revealed that the ISFSF surface must be increased by 7,000m^2, from 24,000m^2 to 31,000m^2 respectively. It should also be noted that in the first Scenario the land area used is smaller which would allow building in the future new modules required for storage of the resulting spent fuel from Units 3 and 4.

4.2. Analysis of second scenario

In order to provide the storage for a number of bundles similar to that in Scenario I (612,000 bundles) the number of MACSTOR 200 modules required for this scenario is 44. It follows that to ensure storage of spent fuel bundles resulting from the operation of Units 1 and 2 with 2 cycles of life a number of fifty-one MACSTOR 200 modules on 6 rows will be required. To achieve this scenario, like in the first scenario, 1,020 storage cylinders and 10,200 storage baskets for the spent fuel are necessary, the maximum storage capacity being 612,000 bundles. The calculations revealed that the ISFSF area will be increased by 14,000m^2, from 24,000m^2 to 38,000m^2 respectively. In the table below the most important technical issues that differentiate the two scenarios according to the storage requirement of an identical number of fuel bundles are emphasised.

Table 2

Parameter	First Scenario	Second Scenario
Total number of stored bundles	612.000	612.000
Number of new gantry cranes which are required	4	6
Draft tanks/cables connections	6 /23	8/30
Water accumulating tanks and containing tanks	22	21
New roads between modules	3	5
New roads and platform area (m^2)	4.500	6.700
New fence for psychical protection (m)	330	375
Premises sewage network (m)	616	860
Storm sewer network in the modules perimeter (m)	2.060	3.120
Storm sewer network gutter laid on the lower base of embankment	655	710

5. <u>Estimated costs of investment</u>

The Spent Fuel Intermediary Storage Facility is modular. The investment is made considering the annual rate of spent fuel discharging from the reactor and its subsequently transfer to ISFSF after at least 6 years of SFT calming.

First Scenario

In this first scenario, in addition to the existing seven 200 MACSTOR modules and twenty-one MACSTOR 400 a number of 2 modules are expected to be built, summing up a total of 30 modules, arranged in four rows.

The table below presents the total expenditure for the First Scenario:

Name of expenses chapters	Value (without VAT)		VAT	Value (VAT included)	
	Thousand lei	Thousand euro	Thousand lei	Thousand lei	Thousand euro
General total amount:	604.567,54	134.348,34	145.096,21	749.663,75	166.591,94
Of which: C+M	300.043,80	66.676,40	72.010,51	372.054,31	82.678,74

Second Scenario

In this second scenario, in addition to the existing seven 200 MACSTOR modules a number of forty-four MACSTOR 200 modules are expected to be built, summing up a total of 51 modules, arranged in six rows.

The table below presents the total expenditure for the Second Scenario:

Name of expenses chapters	Value (without VAT)		VAT	Value (VAT included)	
	Thousand lei	Thousand euro	Thousand lei	Thousand lei	Thousand euro
General total amount:	710.651,36	157.922,52	170.556,32	881.207,68	195.823,93
Of which: C+M	389.889,97	86.642,22	95.573,59	483.463,56	107.436,35

Note: the costs were fixed in lei at the rate of 4.50 lei/euro.

6. <u>Conclusions</u>

The ISFSF storage facility as originally designed with twenty-seven MACSTOR 200 can only provide the storage capacity for Units 1 and 2 for a cycle of operation, so it is clear the need to extend the dry storage capacity for the spent nuclear fuel.

As a result, CITON analysed in its work two scenarios to identify the most feasible technical and economic scenario:

First Scenario

In this first scenario, in addition to the existing seven MACSTOR 200 modules, a number of forty-four MACSTOR 200 modules and twenty-one MACSTOR 400 modules are expected to be built, summing up a total of 30 modules, arranged in four rows.

Second Scenario

In this second scenario, in addition to the existing seven 200 MACSTOR modules a number of forty-four MACSTOR 200 modules are expected to be built, summing up a total of 51 modules, arranged in six rows.

The main advantages of the first scenario compared to the second one are as follows:

- Efficient use of available space, which is a very important advantage given that the solution to increase the storage capacity must be based mainly on the intensive use of good foundation land in terms of geological and geotechnical requirements;
- Keeping an identical mode of operation through compatibility with the existing equipment (gantry crane, spent fuel storage basket, transfer container, loading guide, etc.);
- The size and characteristics of MACSTOR 400 module allow that the transition from MACSTOR 200 module to MACSTOR 400 module requires no major changes in the current arrangement of modules rows within ISFSF;
- The land area used is smaller which would allow building in the future new modules required for storage of the resulting spent fuel from Units 3 and 4.
- A small number of earthworks required for the electrical installations related to the constructions;
- Smaller building materials quantities;
- Lower cost per fuel bundle stored in ISFSF;
- Lower cost of investment: the first scenario requires an investment amounting to 604,567.54 lei without VAT (134,348.34 thousand euros), while the second scenario requires an investment of 710,651.36 lei without VAT, resulting in a savings of 106,083.82 thousand lei.

After analysing the two ISFSF extension scenarios in term of technical and economic issues resulted that the first scenario is the most advantageous.
The conclusion of the above-mentioned issues is that the transfer to the MACSTOR 400 module is necessary, feasible and advisable. The first module of this type will be module no. 10 located on row number 2.