## *11.2 Attachments to Chapter 2*

**Attachment 11.2.1: Comparison and justification of decommissioning alternatives based on the EWN experience in Greifswald NPP and V1 NPP Bohunice, Units 1 and 2**

**Attachment 11.2.2: Estimated resources for the Investment Proposal implementation according the Up-dated Decommissioning Strategy KMPU/DCS/001**

# *Attachment 11.2.1 Comparison and justification of decommissioning alternatives based on the EWN experience in Greifswald NPP and V1 NPP Bohunice, Units 1 and 2*

## 1. Justification of the alternatives based on the EWN experience in Greifswald NPP

In the frame of the decision finding process concerning the decommissioning strategy for Unit 1 to 5 of the Greifswald NPP (Cost estimation for the Deferred Dismantling of the Greifswald NPP, from January 1995, author NIS company) the different decommissioning alternatives were assessed on the base of calculated expenses and estimated doses. [56]

The first step was to research an optimized alternative for the Safe Enclosure and the second one was the comparison of this alternative with the immediate dismantling alternative.

The following alternatives of Safe Enclosure were assessed:

- A1: Reactor Safe Enclosure:
  A1a) Reactor Pressure Vessel (RPV) in the building;
  A1b) RPV removal and storage in an external building.
- A2: Safe Enclosure area is limited to the pressurized room systems and the Spent Fuel Pools;
- A3: Safe Enclosure of the Reactor Buildings;
- A4: Safe Enclosure of the Reactor Buildings and the Auxiliary Buildings.

To aid the decision process, a matrix was developed by the Company NIS as Contractor and EWN. Each of the 20 defined part measures for the realization of the alternatives was assessed with weighting factors (1-10) for the expenditures, costs and collective radiation doses (personnel).

The part measures with high influence to cost or dose had the weighting factor 10.

The results are shown in the following table 1-1 (source [50])

**Table 1-1 Decision matrix of alternatives for Safe Enclosure (SE) [50]**

| Measures | Expenditure | | | | | Weighting factors | |
|---|---|---|---|---|---|---|---|
| | A1a) | A1b) | A2 | A3 | A4 | Exp. | Dose |
| Dismantling expenditure | 6 | 8 | 4 | 2 | 1 | 10 | 10 |
| Licensing expenditure | 5 | 7 | 4 | 3 | 4 | 10 | 0 |
| Groundwater lowering* | 3 | 1 | 3 | 3 | 3 | 6 | 0 |
| SE operation expenditure | 2 | 1 | 3 | 4 | 5 | 6 | 4 |
| New installations construction | 3 | 6 | 4 | 3 | 4 | 5 | 9 |
| Maintenance SE | 1 | 1 | 3 | 4 | 5 | 6 | 6 |
| Remote dismantling | 5 | 5 | 5 | 5 | 1 | 5 | 6 |
| New stacks | 5 | 2 | 5 | 5 | 0 | 2 | 0 |
| Abrasion of contaminated concrete | 5 | 5 | 4 | 3 | 2 | 6 | 4 |
| Complexity of enclosure | 2 | 1 | 3 | 4 | 5 | 1 | 2 |
| Security services | 3 | 1 | 3 | 3 | 4 | 5 | 0 |

| Measures | Expenditure | | | | | Weighting factors | |
|---|---|---|---|---|---|---|---|
| | A1a) | A1b) | A2 | A3 | A4 | Exp. | Dose |
| Operating systems in the SE area | 1 | 1 | 3 | 4 | 5 | 1 | 0 |
| Supervision of radiation protection | 4 | 1 | 4 | 4 | 7 | 3 | 0 |
| Reconstruction of building structures | 3 | 1 | 3 | 3 | 7 | 10 | 2 |
| Detailed knowledge of staff / documentation | 2 | 1 | 3 | 4 | 5 | 3 | 3 |
| preparation for later dismantling | 2 | 1 | 3 | 4 | 5 | 8 | 3 |
| Later dismantling | 2 | 1 | 3 | 4 | 5 | 8 | 8 |
| Storage of waste | 5 | 5 | 3 | 2 | 1 | 7 | 2 |
| New installation of facilities for SE | 2 | 1 | 3 | 4 | 5 | 5 | 4 |
| Maintenance of the monitored area | 3 | 1 | 4 | 1 | 1 | 6 | 2 |
| **Sum expenditure** | **64** | **51** | **70** | **69** | **75** | | |
| **Ass. expenses (ExW)** | **387** | **342** | **393** | **365** | **419** | | |
| **Ass. dose (ExW)** | **186** | **174** | **196** | **194** | **192** | | |
| **Ass. dose + expenses** | **573** | **516** | **589** | **559** | **611** | | |

*(ExW = product of expenditure and weighting).*
*(Ass. = assessment).*
** decreasing the groundwater level of the site*

According to this assessment matrix the alternative A1b), the removal and separate storage of the RPV, is the best due to minimum of expenses and dose. But in 1995 were expected uncertainties by the licensing procedure and the place of storage. Thus the alternative A3 was favored.

The results of the next step, the comparison of the optimum alternative for Safe Enclosure with the immediate dismantling alternative, can be seen in the following table 1-2.

**Table 1-2 Comparison of the optimum alternative for Safe Enclosure with the immediate dismantling alternative**

| Parameter | Immediate dismantling | Dismantling after Safe Enclosure |
|---|---|---|
| Expenses (Million DM) | 5 110 | 6 077 |

| Parameter | Immediate dismantling | Dismantling after Safe Enclosure |
|---|---|---|
| Collective Dose (manSv) | 17.03 | 20.20 |

Additional aspects for the decision of the immediate dismantling were:

1. Staff with detailed knowledge;
2. Mitigation of the social impacts;
3. The district Western Pomerania is a structure weak region with a high unemployment rate, thus the industrial use of the site as soon as possible is necessary;
4. Creation of detailed knowledge and experience for decommissioning and dismantling of WWER type reactors, usable for other NPP decommissioning projects.

The experience from the decommissioning process in the Greifswald NPP confirmed the decision made for Continuous Dismantling.

The real Collective Dose of the whole decommissioning process in the Greifswald NPP can be estimated at the present state (> 88%) with about 5 manSv and thus about one third of the dose calculated in 1995.

**2. Comparison of different Decommissioning Alternatives for V1 NPP Bohunice**

The Slovak Republic undertook a commitment to Shutdown Units 1 and 2 of Jaslovské Bohunice V1 NPP in 2006 and 2008 respectively, as a condition for fulfilling the Accession Agreement of the Slovak Republic to the European Union.

The Bohunice V1 NPP consists of 2 Units WWER-440 model 230 with the same Technical design as the KNPP Units 1 and 2.

In the frame of the decommissioning preparation an EIA Report was elaborated with the goal to assess and compare impacts of all proposed decommissioning alternatives to recommend the most suitable alternative.

The assessed alternatives were:

- Alternative 1 – Immediate decommissioning alternative (IDO);
- Alternative 2 - Deferred decommissioning alternative with Safe Enclosure under surveillance for 30 years (SES);
- Alternative 3 - Deferred decommissioning alternative with reactor Safe Enclosure for 30 years (RSE).

These Alternatives were compared with Zero Alternative, which represents the situation and its consequences, if the proposed activity – V1 NPP decommissioning, would not take place.

**Table 2-1 Summary of main parameters for Alternatives 1, 2 and 3 (Source [18])**

| *Parameter* | *Alternative 1* | *Alternative 2* | *Alternative 3* |
|---|---|---|---|
| Total costs [SKK mill.] | 17 624.48 | 15 809.93 | 15 435.07 |
| Collective effective dose (CED) [manSv] | 13.8778 | 8.1734 | 13.2333 |
| Duration of the decommissioning process under authorization for decommissioning [year] | 14 | 52 | 52 |
| Labor hours needed [$10^3$ hours] | 15 026.5 | 13 498.4 | 12 891.1 |
| Amount of liquid radioactive waste (at 200 g/dm$^3$ salinity) [m$^3$] | 1 930 | 1 774 | 1 931 |
| Radioactivity of gaseous discharges [Bq] | 3.22 $10^6$ | 2.04 $10^6$ | 3.27 $10^6$ |
| Radioactivity of liquid discharges [Bq] | 7.94 $10^7$ | 5.04 $10^7$ | 8.08 $10^7$ |
| Amount of released metals to the environment [t] | 55 996 | 61 004 | 59 867 |
| Amount of recyclable construction waste [t] | 418 125 | 318 734 | 318 599 |
| Amount of communal waste [t] | 3 331 | 7 855 | 7 883 |
| Number of fiber-concrete containers for Near Surface Repository at Mochovce [pcs] | 1 038 | 886 | 1 050 |
| Number of fiber-concrete containers for Interim Radioactive Waste Storage Facility [pcs] | 44 | 30 | 30 |
| Time load of the site by radioactivity [year] | 13.7 | 51 | 51 |

A multicriterion analysis was carried out for the selection of the most suitable Decommissioning Alternative a multicriterial analysis was carried out, the results being summarized in Table 2-2.

Thirteen evaluation criteria were defined and their criterion weight (from 1 up to 10) [18] was determined by a group of experts.

**Table 2-2 Final results of multicriterion analysis [18]**

| *No.* | *Description* | *Contribution of criterion to the alternative value* | | |
|---|---|---|---|---|
| | | *Alternative 1* | *Alternative 2* | *Alternative 3* |
| | Safety criteria | | | |
| 1 | Total Collective effective Dose | 11.799 | 6.949 | 11.251 |
| | Environmental criteria | | | |
| 2 | Radiation consequences of gaseous discharges to environment | 5.662 | 3.587 | 5.750 |
| 3 | Radiation consequences of liquid discharges to environment | 5.655 | 3.590 | 5.755 |
| 4 | Time load of site by radioactivity | 2.131 | 7.934 | 7.934 |
| 5 | Amount of non-utilizable waste | 1.048 | 2.472 | 2.480 |
| | Economic criteria | | | |
| 6 | Total costs | 8.655 | 7.764 | 7.580 |
| 7 | Time distribution of costs | 4.000 | 10.667 | 9.333 |
| 8 | Labor hours needed | 5.442 | 4.889 | 4.669 |
| | Implementation criteria | | | |
| 9 | Continuity of manpower and RAW processing facilities utilization | 4.235 | 11.294 | 8.471 |
| 10 | Time of final site release | 2.492 | 9.254 | 9.254 |
| 11 | Preparedness of site for further utilization | 1.000 | 4.000 | 4.000 |
| | Criteria of demands for RAW repositories | | | |
| 12 | Total number of Fiber Concrete Container (FCC) into Near Surface Repository | 8.377 | 7.150 | 8.473 |
| 13 | Total number of FCC into RAW Interim Storage | 10.154 | 6.923 | 6.923 |
| | Alternative value - $S_j$ | 70.651 | 86.473 | 91.875 |

*Source: Bohunive NPP V1 EIA report during decommissioning [18].*
*CED = Collective Effective Dose, FCC = Fiber Concrete Container (RAW), NSR = Near Surface Repository; ISRAW = Interim Storage for Radioactive Waste*

The result of assessment of the alternatives was the selection of the alternative 1 V1 NPP immediate decommissioning) as most suitable alternative. The alternative of V1 NPP immediate decommissioning has more advantages in comparison with the other assessed alternatives:

- High availability and reliability of information on design and operational history of V1 NPP.
- High potential for using the existing structures, systems and components in the decommissioning process such as ventilation, dosimetric system, cranes, barriers, etc.
- It enables an effective use of existing facilities for treatment and conditioning of RAW.
- Continuity of employment in the region, because a higher number of trained, skilled and experienced staff can be engaged in the decommissioning immediately after the final shutdown of V1 NPP.

# *Attachment 11.2.2 Estimated resources for the Investment Proposal implementation according the Up-dated Decommissioning Strategy KMPU/DCS/001*

**Table 1 Costs of Units 1-4 KNPP pre-decommissioning activities, operation in "E" mode and decommissioning first stage activities (2011 - 2018), according to [7]**

| Activities | Years for activities performance | Performance costs (labour, other expenses and contingencies) [MEUR] | Investment cost [MEUR] | Total cost [MEUR] |
|---|---|---|---|---|
| **01 - Pre-decommissioning actions** | | 2,94 | | 2,94 |
| | 2007 | 1.44 | - | 1.44 |
| | 2008 | 1.095 | - | 1.095 |
| | 2009 | 0.405 | - | 0.405 |
| **02- Operation in "E" mode** | | 13.236 | | 13.236 |
| | 2007 | 2.541 | - | 2.541 |
| | 2008 | 2.541 | - | 2.541 |
| | 2009 | 2.541 | - | 2.541 |
| | 2010 | 1.54 | - | 1.54 |
| | 2011 | 1.54 | - | 1.54 |
| | 2012 | 1.54 | - | 1.54 |
| | 2013 | 0.693 | - | 0.693 |
| **03- Procurement of General Equipment and Material** | | 37.277 | 74.949 | 112.226 |
| Dry Spent Fuel Storage Facility (Project 1) | 2004-2008 | 4.441 | 48.7 | 53.141 |
| Installation for treatment of Low level liquid waste treatment facility (Project 2) | 2005-2006 | 0.964 | 1.185 | 2,149 |
| Supply of hardware and software related to security (Project 3a) | 2005 | 0.614 | 0.596 | 1.21 |
| Supply of Physical Barriers and Access Points (Project 3b) | 2005 | 0.614 | 0.178 | 0.792 |
| Decontamination and water treatment equipment supply (Project 4) | 2006-2007 | 0.656 | 0.829 | 1.485 |
| Supply of Facility for spent ion exchange resins retrieval and conditioning (Project 5a) | 2006-2008 | 1.371 | 2.780 | 4.151 |
| Solid RAW High volume reduction factor facility (Project 5b) | 2007-2012 | 7.456 | 9.50 | 16.956 |

| Activities | Years for activities performance | Performance costs (labour, other expenses and contingencies) [MEUR] | Investment cost [MEUR] | Total cost [MEUR] |
|---|---|---|---|---|
| Free Release Measurements Facility of RW (Project 6a) | 2006-2007 | 0.656 | 0.480 | 1.136 |
| Equipment for radiological inventory Project 6B | 2006-2007 | 0.656 | 0.277 | 0.933 |
| Personnel Redressing and Decontamination Facility (Project 7) | 2006-2007 | 0.656 | 0.424 | 1.08 |
| Facility for retrieval of solidified phase of evaporator concentrate tanks (Project 9b) | 2009-2011 | | | 22.534 |
| Size reduction and decontamination workshop | 2009-2011 | 3.867 | 10.00 | 13.867 |
| KPMU | 2003 | 2.456 | | 2.456 |
| | 2013 to 2018 | 12.87 | | 12.87 |
| **04 - Dismantling Activities** | | 41.5757 | | 41.5757 |
| | 2007 | 0.9955 | | 0.9955 |
| | 2008 | 1.4842 | | 1.4842 |
| | 2009 | 1.991 | | 1.991 |
| | 2009 | 2.715 | | 2.715 |
| | 2010 | 2.715 | | 2.715 |
| | 2011 | 2.715 | | 2.715 |
| | 2012 | 3.62 | | 3.62 |
| | 2013 | 4.344 | | 4.344 |
| | 2014 | 5.249 | | 5.249 |
| | 2015 | 5.249 | | 5.249 |
| | 2016 | 5.249 | | 5.249 |
| | 2017 | 5.249 | | 5.249 |
| | 2018 | 5.249 | | 5.249 |
| **05 – Waste management** | | 46.751 | 2.5 | 49.251 |
| | 2007 | 0.7425 | | 0.7425 |
| | 2008 | 0.99 | | 0.99 |
| | 2009 | 1.2045 | | 1.2045 |

| Activities | Years for activities performance | Performance costs (labour, other expenses and contingencies) [MEUR] | Investment cost [MEUR] | Total cost [MEUR] |
|---|---|---|---|---|
| | 2010 | 1.65 | | 1.65 |
| | 2011 | 1.65 | | 1.65 |
| | 2012 | 1.65 | | 1.65 |
| | 2013 | 1.32 | | 1.32 |
| | 2014 | 1.32 | | 1.32 |
| | 2015 | 1.155 | | 1.155 |
| | 2016 | 1.155 | | 1.155 |
| | 2017 | 0.99 | | 0.99 |
| | 2018 | 0.825 | | 0.825 |
| Delivery of liquid RAW to SE "RAW" for conditioning and disposal" | 2016-2018 | 19.866 | | 19.866 |
| Delivery of RAW generated during dismantling to SE "RAW" for disposal | 2016-2018 | 8.037 | | 8.037 |
| Decontamination of contaminated areas around auxiliary building 1 | 2009-2013 | 3.393 | | 3.393 |
| Construction of conventional waste repositiry and waste transportation to the facility for disposal | 2013 -2018 | 0.8 | 2.5 | 3.3 |
| **06 Site Surveillance and Maintenance** | | 59.271 | | 59.271 |
| | 2007 -2011 | 28.875 | | 28.875 |
| | 2012- 2014 | 14.46 | | 14.46 |
| | 2015 - 2018 | 15.936 | | 15.936 |
| **07- Project management and engineering** | | 20.587 | | 20.587 |
| | 2007 – 2009 | 4.575 | | 4.575 |
| | 2010 - 2013 | 6.952 | | 6.952 |
| | 2014 - 2018 | 9.06 | | 9.06 |
| **08-SNF Management after its removal from the units** | | 9.063 | | 9.063 |
| | 2009-2018 | 9.063 | | 9.063 |

| Activities | Years for activities performance | Performance costs (labour, other expenses and contingencies) [MEUR] | Investment cost [MEUR] | Total cost [MEUR] |
|---|---|---|---|---|
| **Total** | | **230.707** | **77.449** | **330.682** |

**Table 2 Estimated personnel for Units 1-4 activities performance during the period 2007 to 2018**

| Years | Personnel needed for carrying out activities under: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 01 Pre - decommissioning | 02 Operation in "E" mode and fuel removal from the Units | 03 Procurement of General Equipment and Material | 04 Dismantling activities, including preparation of reactor building for safe enclosure | 05 Conventional waste and RAW management | 06 Site surveillance and maintenance | 07 Project management and engineering | 08 Spent fuel management after removal from the Units |
| 2007 | 96 | 165 | 25 | 55 | 45 | 300 | 30 | |
| 2008 | 73 | 165 | 25 | 82 | 60 | 300 | 30 | |
| 2009 | 27 | 165 | 30 | 110 | 73 | 300 | 30 | 53 |
| 2010 | | 100 | 30 | 150 | 100 | 300 | 40 | 53 |
| 2011 | | 100 | 30 | 150 | 100 | 300 | 40 | 53 |
| 2012 | | 100 | 30 | 150 | 100 | 250 | 40 | 53 |
| 2013 | | 45 | 25 | 200 | 80 | 250 | 40 | 53 |
| 2014 | | | 25 | 240 | 80 | 250 | 45 | 53 |
| 2015 | | | 25 | 290 | 70 | 200 | 45 | 53 |
| 2016 | | | 25 | 290 | 70 | 200 | 45 | 53 |
| 2017 | | | 25 | 290 | 60 | 200 | 45 | 53 |
| 2018 | | | 25 | 290 | 50 | 200 | 45 | 53 |

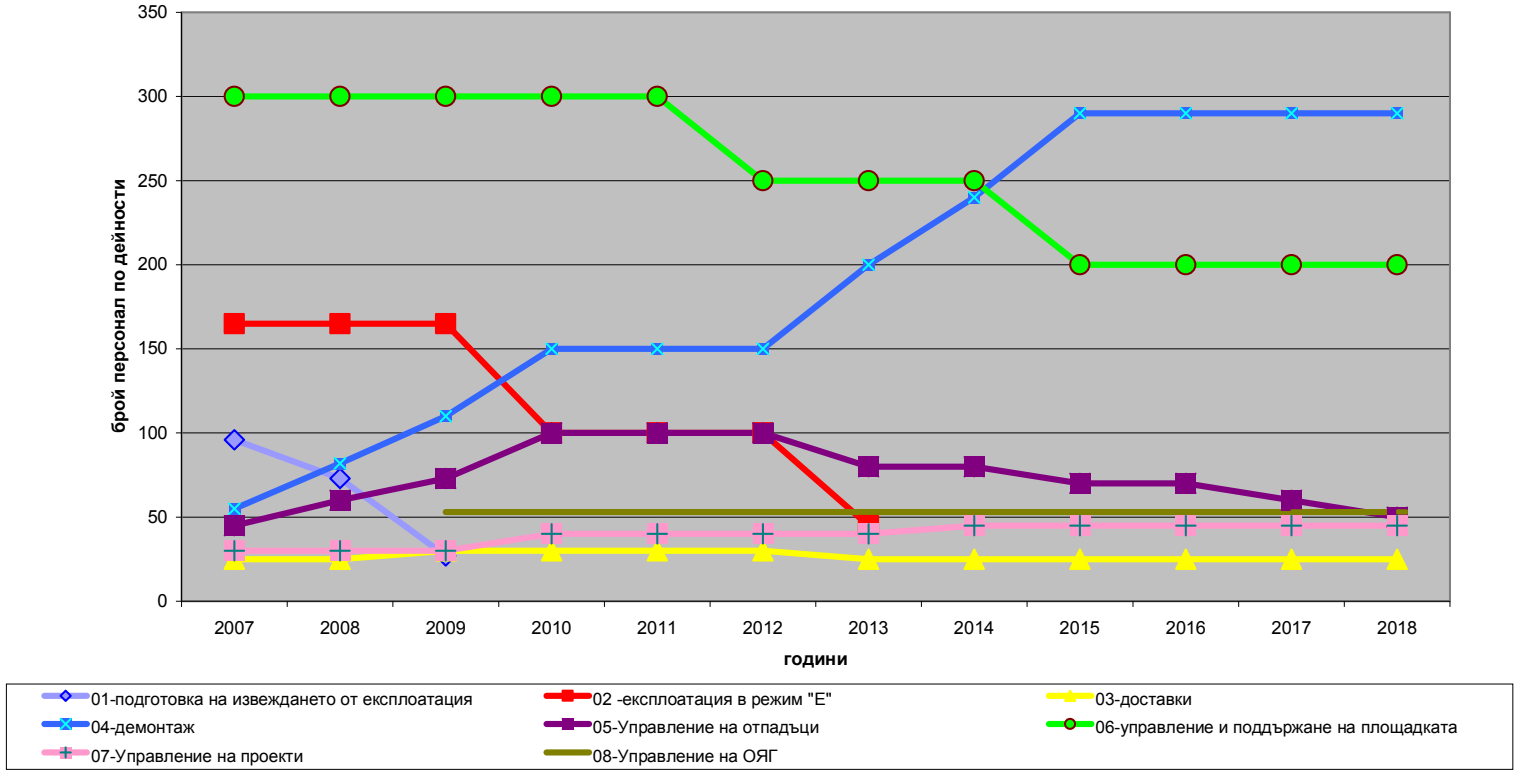


**Fig. 1: Personnel needed for the performance of the activities at Units 1-4 during the period 2007-2018 by years**

1 - pre-decommissioning
02 - operation in “E” mode
03 - supplies
04 - dismantling
05 - waste management
06 - site surveillance and maintenance
07 - project management
08 - SNF management

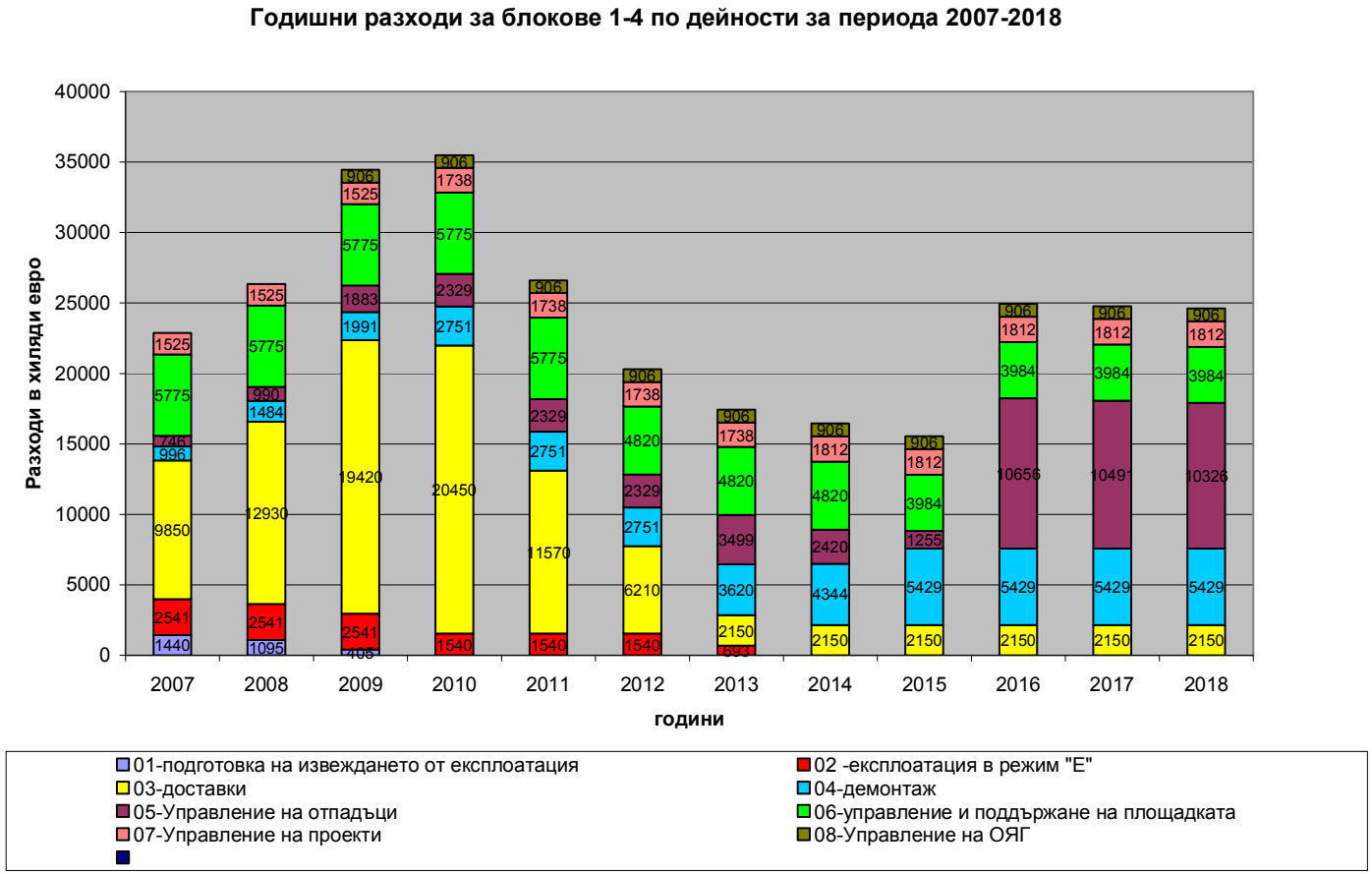


**Fig. 2: Annual expenses by activities for units 1-4 during the period 2007-2018**

01 - Decommissioning preparation, 02 - Operation at regime E, 03 - Provision of equipment and materials, 04 - Dismantling
05 – Management of RAW, 06 – Management and maintenance of the site, 07 – Management of the project, 08 – Management of spent fuel,

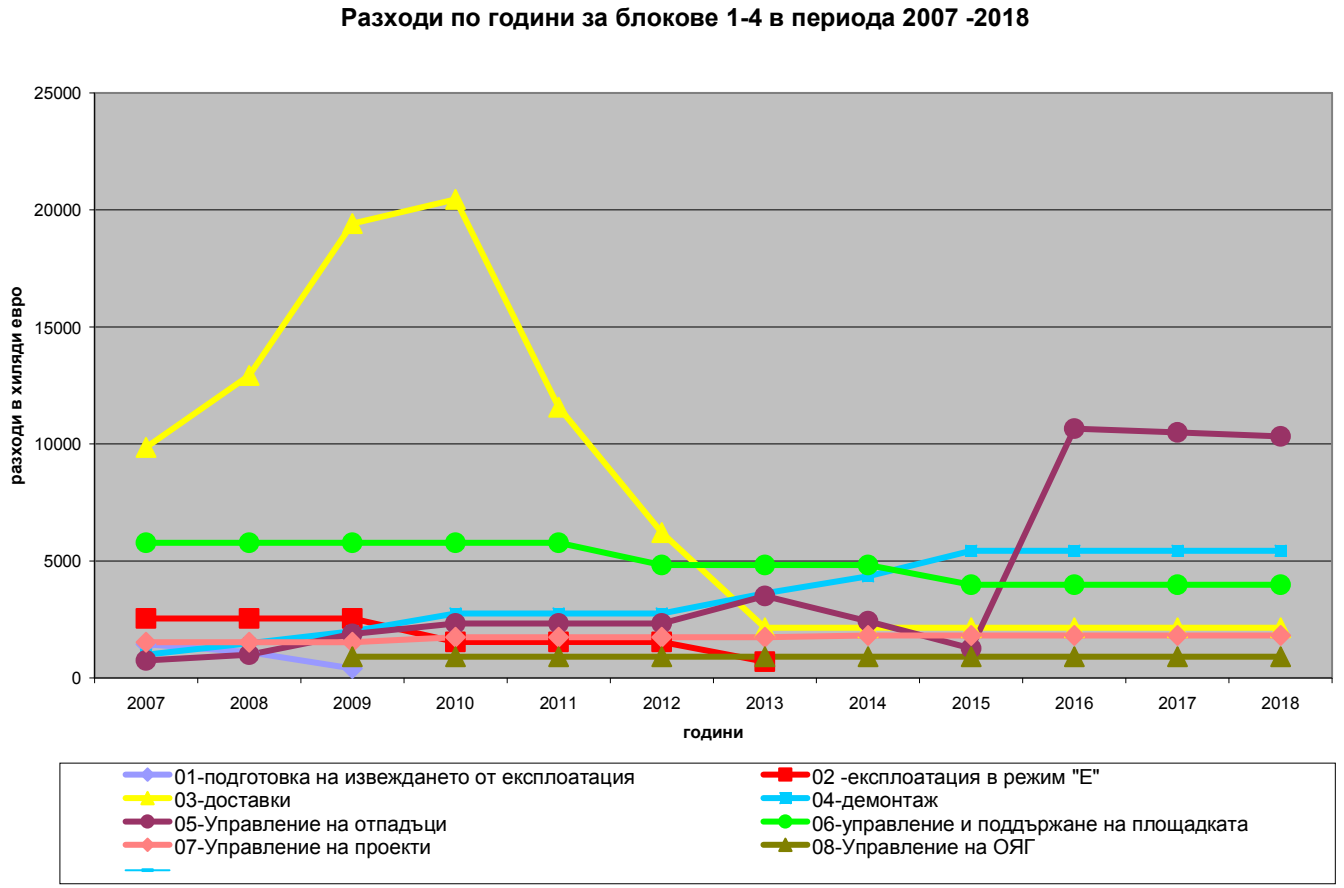


**Fig. 3: Annual expenses by years during 2007-2018**

01 - Decommissioning preparation, 02 - Operation at regime E, 03 - Provision of equipment and materials, 04 - Dismantling
05 – Management of RAW, 06 – Management and maintenance of the site, 07 – Management of the project, 08 – Management of spent fuel


**Fig. 4: Personnel flow during the decommissioning of Units 1-4 during the period 2007-2035**

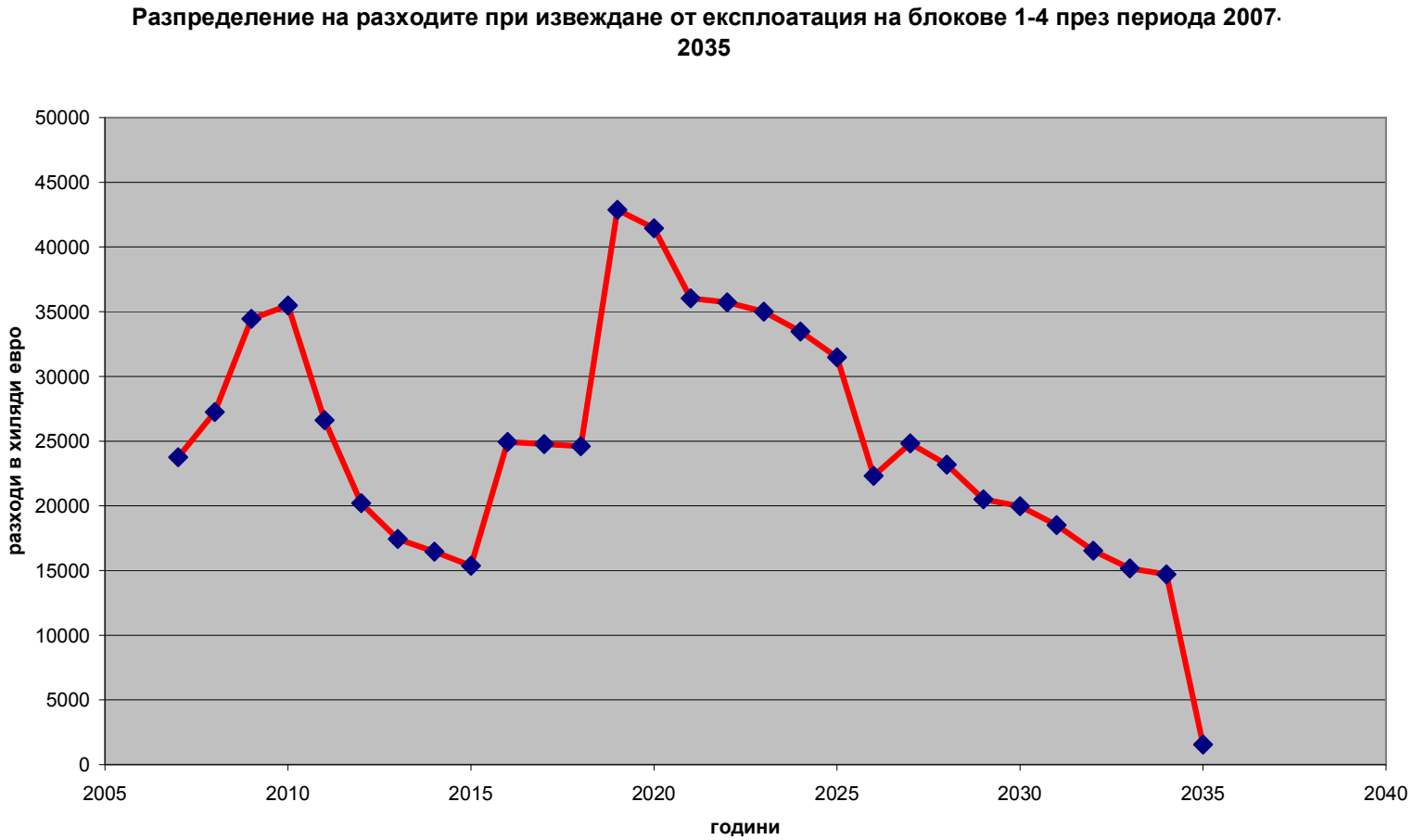


**Fig. 5 Decommissioning Cost Break-down Units 1-4 during the period 2007 - 2035**