The Bohunice V1 NPP Final Conceptual Decommissioning Plan and what was next

Selected Lessons Learned and Good Practices from Bohunice V1 NPP Decommissioning

The First Knowledge Product prepared based on Council Regulation No. 2021/100 by Bohunice Programme

Outline

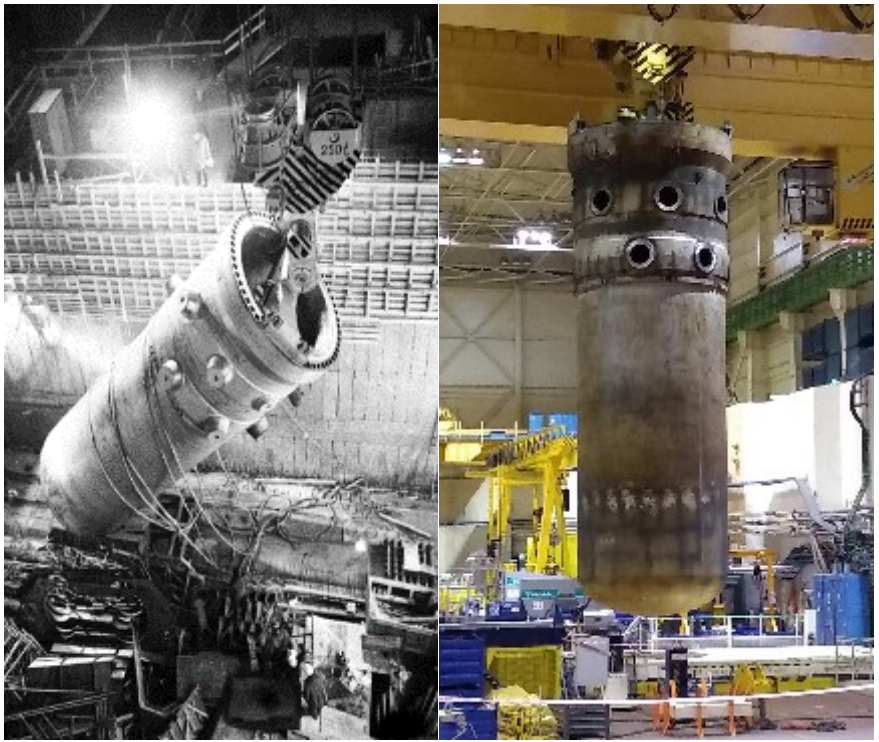
1. Introduction to JAVYS and V1 NPP
2. General Context
3. Goal
4. The Need for this Knowledge Product
5. Development of the V1 NPP Final Conceptual Decommissioning Plan (FCDP)
6. Conceptual set-up of the decommissioning projects
7. Conclusions
8. Value
9. Abbreviations
10. References

Demolition of V1 NPP cooling towers

Ministry of Economy of the Slovak Republic is the sole JAVYS, plc. shareholder.

Overtake of responsibility, activities, staff structure, technology & property at 1.4.2006 from the company "Slovenské elektrárne".

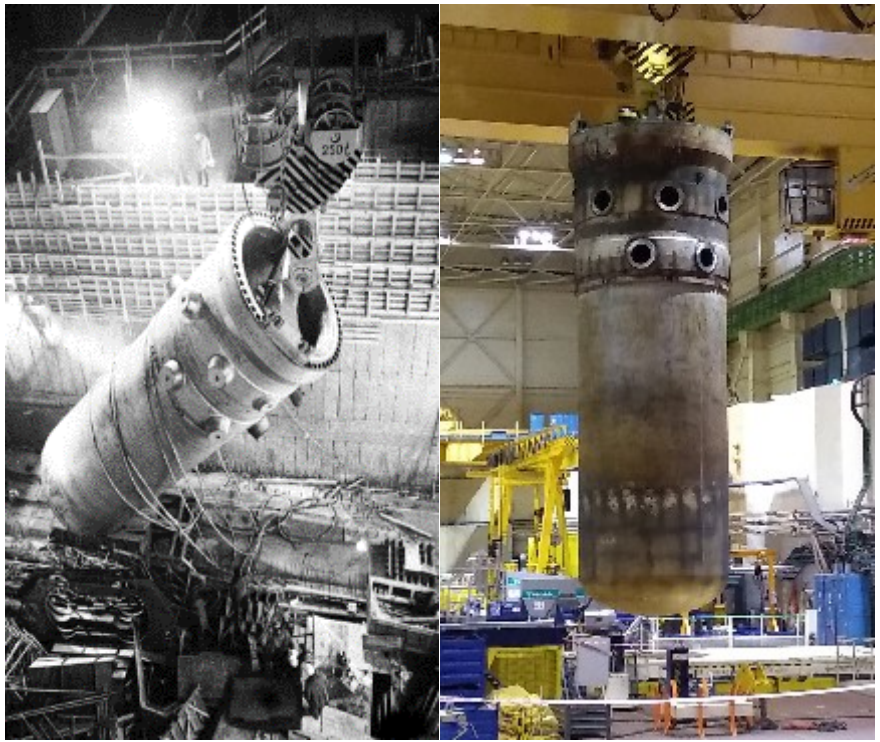
V1 NPP RPV Installation (1976) / Removal (2021)



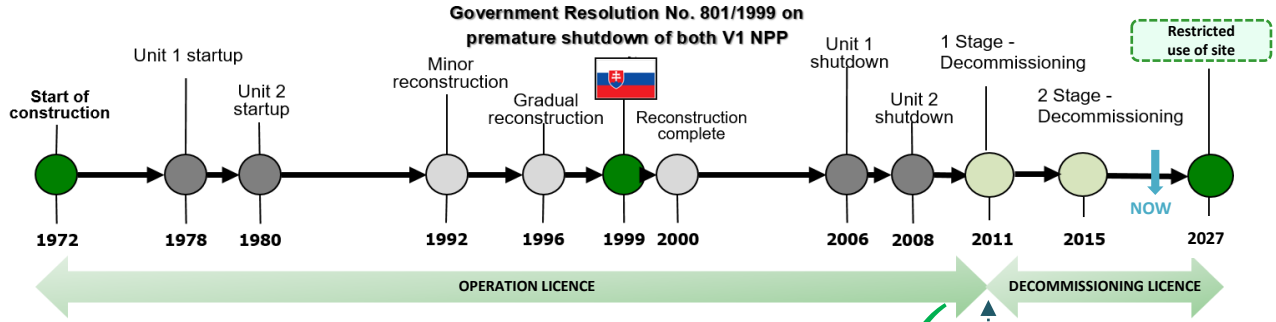
Company's nuclear activities:

- A1 NPP and V1 NPP Decommissioning
- RAW Management (from cradle to grave)
- Nuclear Spent Fuel Management
- Institutional RAW & Collected RCM Management
- Tasks related to new NPP/DGR construction

V1 NPP RPV Installation (1976) / Removal (2021)



BASIC INFORMATION ABOUT V1 NPP



REACTOR TYPE: 2 x WWER 440-V230

THERMAL OUTPUT: 1375 MW_T

FUEL: UO_2 (1.8 / 2.4 / 3.6 % U-235) (modified 3.82 % U-235)

MODERATOR AND COOLANT: H_20

NUMBER OF LOOPS: 6

In progress

OPERATION TERMINATION

- Spent Nuclear Fuel aftercooling and transport to ISFS
- Preparation for decommissioning
- NPP modifications
- Decommissioning licensing
- Monitoring

STAGE 1
DISMANTLING OF NON-ACTIVE SYSTEMS

- Dismantling of non-active equipment
- Demolition of non-active buildings
- Monitoring systems
- F&D equipment
- Monitoring
- Treatment of historical RAW (except for RH waste storage)

STAGE 2
DISMANTLING OF ACTIVE SYSTEMS

- Dismantling of contaminated and activated equipment
- Demolition of buildings
- RAW management
- Free release of materials
- Monitoring
- Emptying and dismantling of RH waste storage

Financed by Slovak and European Union financial resources

- Requirement of Council Regulation (Euratom) **2021/100** [1]
- **Sharing of knowledge** – tool for increasing of efficiency of the three Programmes` implementation
- **Support** to relevant **European Stakeholders** in Decommissioning area

What is a Knowledge Product?

Tangible output of prepared knowledge that enables action of selected users

- Tangible = explicit knowledge, delivered as a document, service or event
- Prepared = packs knowledge in a format that maximizes impact
- User driven = Is it developed for users
- Actionable = triggers action and eases practical implementation

V1 NPP Knowledge Product topics proposed for years 2021-2027

1. V1 NPP Conceptual Decommissioning Plan and what was next (for 2021)
2. Management of material coming from the V1 NPP decommissioning
3. How to select the strategy for NPPs Reactors decommissioning
4. Decontamination of building surfaces with subsequent demolition of civil buildings
5. Site procedures and measurements in the process of remediation of site
6. Release of the site from administrative control
7. Summary of experience from the V1 NPP decommissioning

Goal: to provide relevant European stakeholders with comprehensive description of decommissioning processes

What is the goal?

Provide users with relevant insights

- selection of optimal decommissioning strategies
- initial decommissioning projects set-up (planning, costing, licensing aspects of nuclear facility decommissioning)

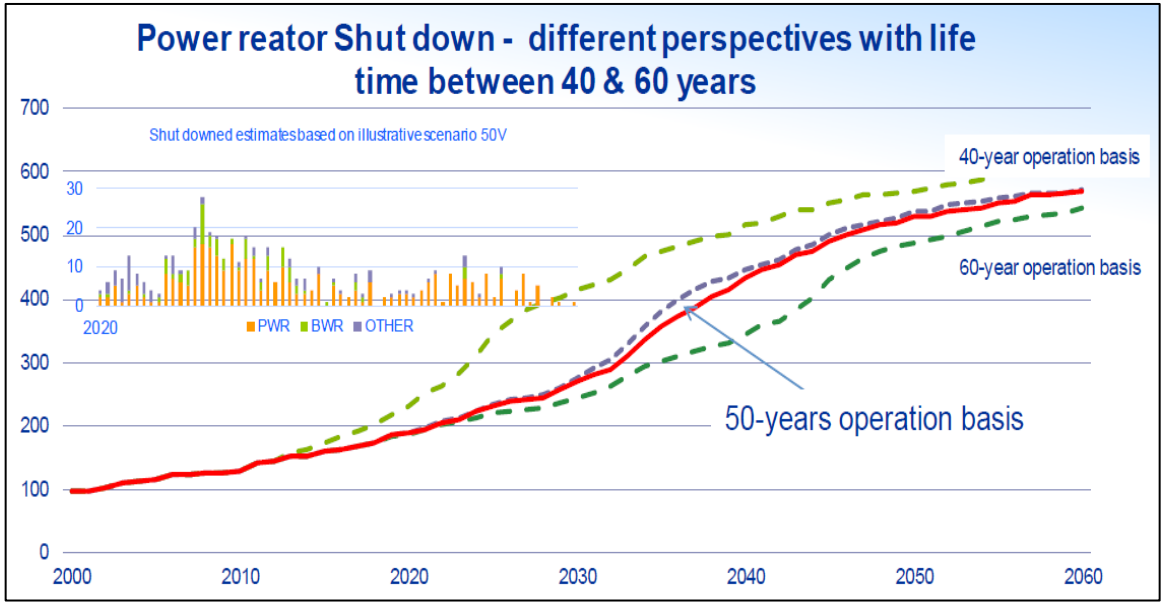
Who may benefit?

Experts
Mid-level managers
Operators, regulatory bodies

- Involved in the preparation of decommissioning processes
- Responsible for the preparation of National decommissioning programs
- Young professionals in schools of decommissioning

4. The Need for Knowledge Product No.1

- Based on IAEA predictions the intensity of decommissioning is expected to increase in the immediate future
- Typically, each nuclear facility decommissioning process starts with a Preliminary Conceptual Decommissioning Plan (FCDP), while still in operation by its operator
- Many FCDP that will be prepared in the forthcoming years may benefit from the experiences share in this knowledge product



IAEA perspective on World-wide/European NPP shut down [2]

Goal of the FCDP

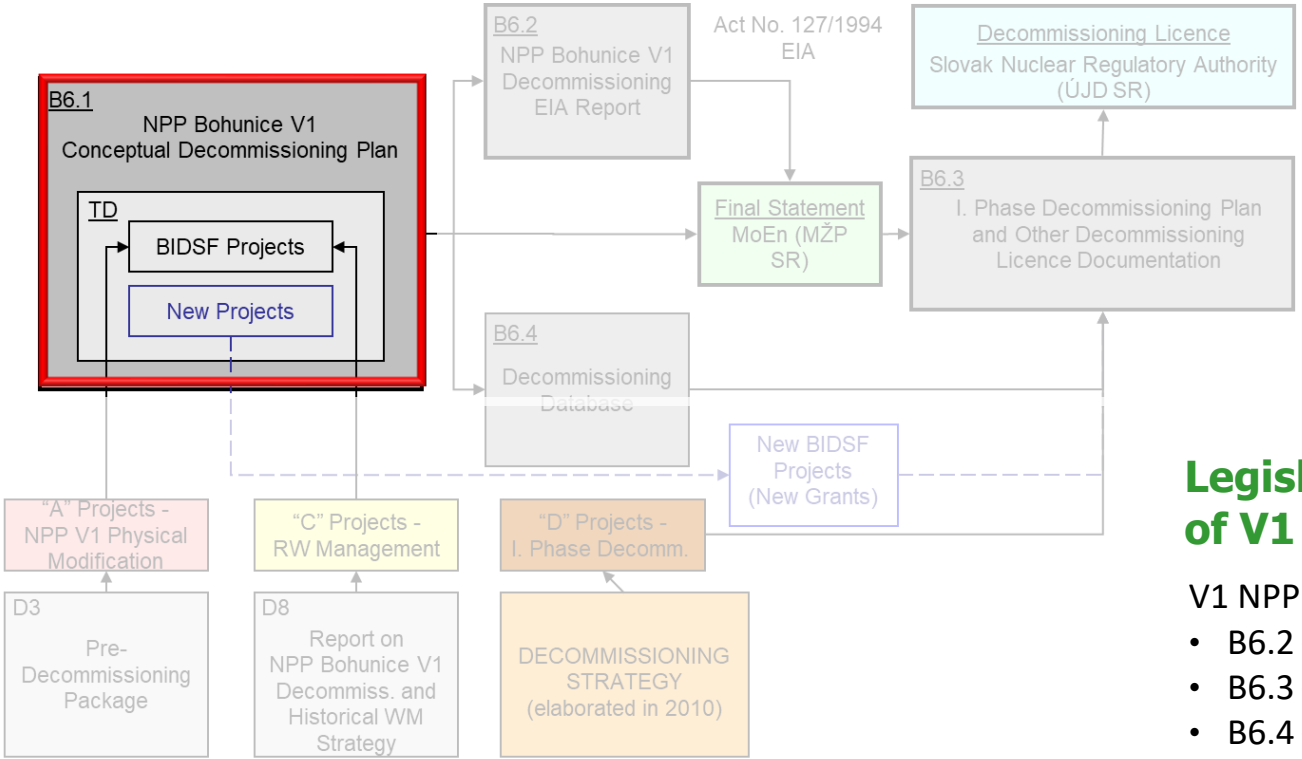
1. To select the optimal decommissioning alternative and demonstrate its financial, technical and environmental feasibility / expedience for relevant stakeholders

2. To provide crucial reference document for EIA process/Stage Decommissioning plan/ Decommissioning Database and updating of National Programme

Key aspects of the FDCP

1. Based on preliminary CDP, which considered knowledge of NPP (design/development/ operation/safety issues, cost estimation and new available best technologies /technics, etc.)[4]
2. Defined alternatives must consider immediate and deferred decommissioning options, [4]
3. Included proposal of conceptual decommissioning projects scope/division set-up
4. Outputs of FCDP must be in accordance with National Programme for handling of SF and RAW [5]

5. Development of the V1 NPP Final Conceptual Decommissioning Plan (FCDP)



Legislation context of V1 NPP FCDP

V1 NPP FCDP a reference for

- B6.2 – Report on EIA process
- B6.3 – The First Stage Decom. Plan
- B6.4 – V1 NPP Decom. Database

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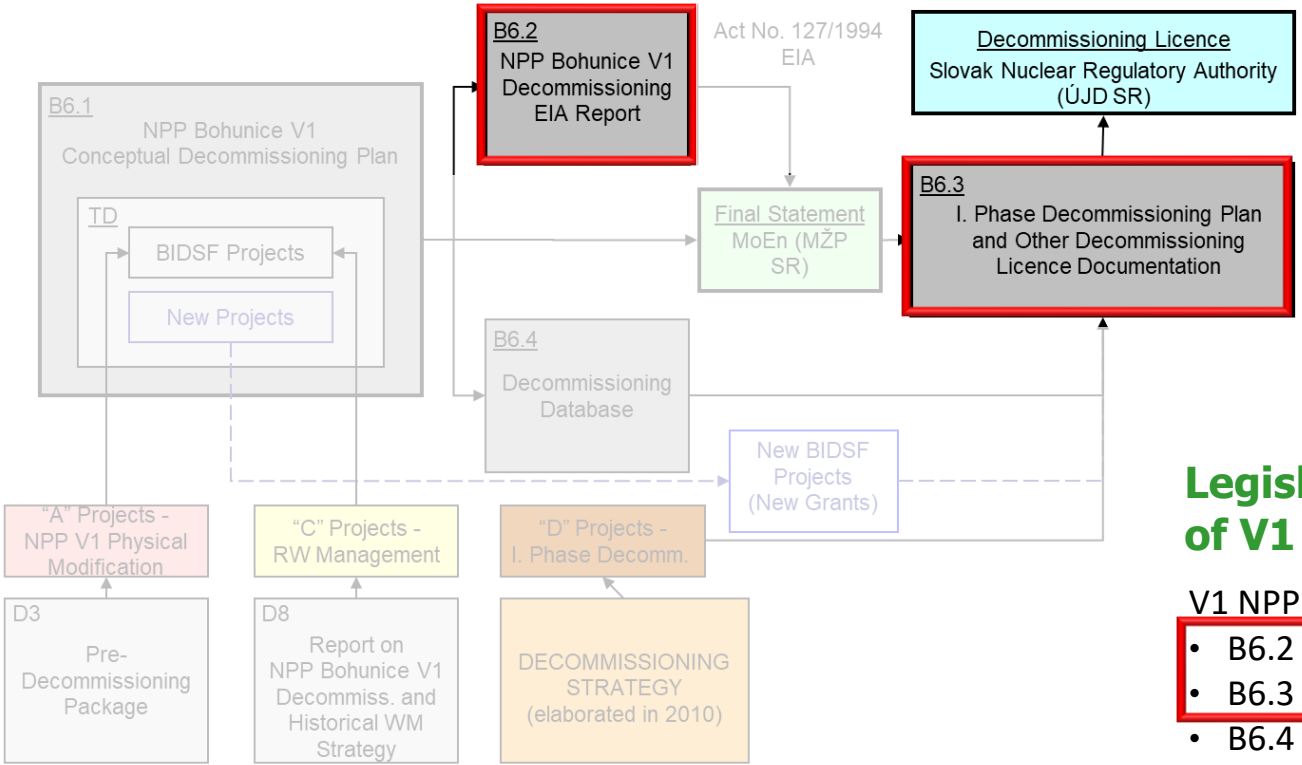

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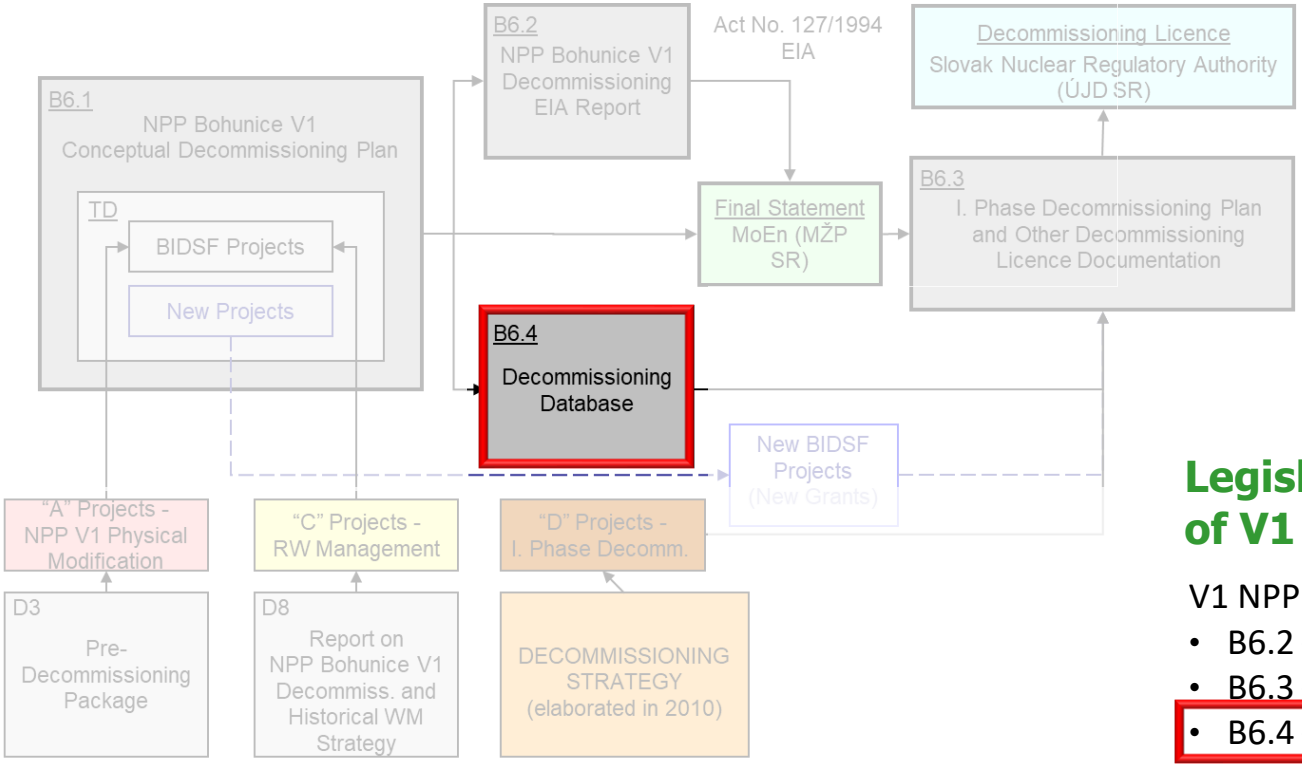

Legislation context of V1 NPP FCDP

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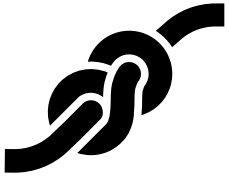
TIP 1

Ensure that level of details in the FCDP is sufficient to feed the EIA report

TIP 2

Promote early interaction with Regulatory authorities to facilitate FCDP approval



TIP 3

Consider requirements of all relevant stakeholders regarding NPP operation termination and decommissioning processes

Conceptual Decommissioning Plan updates:

- more accurate estimation of components and civil structure volumes, weights, radiation characteristics
- analysis of parameters for operation termination (D3) [6] and RAW management facilities availability (D8) [7]

Steps in the FCDP Plan preparation of V1 NPP [3]

- Part 1: Introduction (V1 NPP FCDP need and purpose)
- Part 2: Description of Initial status of V1 NPP and input assumptions and data
- Part 3: Definition of preparatory decommissioning activities
- Part 4: Analysis of decommissioning options
- Part 5: Cost estimation and financial arrangements
- Part 6: Complex comparison of decommissioning options - MCA analysis
- Part 7: Conclusions

TIP 4

Consider expert consultancy support when developing FCDP for the first time

Part 2 - Initial status of V1 NPP and input assumptions and data

Expected initial status of systems and equipment at the start of decommissioning:

- status of systems and equipment
- necessary modifications
- infrastructure (processing facilities, raw repository, etc.)
- preparedness of personnel

Initial assumptions for individual options

- list of civil buildings to be removed
- balance of Conventional, Hazardous and Radioactive materials (dismantling, demolition)
- data on dose rates in the rooms
- technical procedures (decontamination, dismantling, logistics of materials, including storage areas)

Other input data

- working time
- price data,
- labour input,
- consumption of materials, etc.

TIP 5

Keep the qualified personnel familiar with the nuclear facility

Part 3 - Definition of preparatory decommissioning activities

- Separation of the V1 NPP from other nuclear facilities remaining in operation.
- Preparation and implementation of V1 NPP final shutdown and termination of operation.
- Assessment of the state/condition of V1 NPP at the start of decommissioning.
- Ensure the availability of qualified personnel for decommissioning.
- Development of documentation for the V1 NPP decommissioning.
- Provision of new and/or modified infrastructure for the V1 NPP decommissioning.
- Other tasks, such as assessment of legal, technical and other assumptions and requirements for handing-over of the V1 NPP site for decommissioning purposes.

TIP 6

Consider interfaces of surrounding facilities with decommissioned nuclear facility

Examples of preparatory decommissioning activities and projects related to their implementation

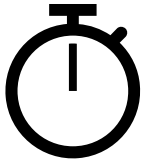
Pre-decommissioning activity	Related projects	Reference		Schedule [month/year]	Costs
0. Coordination, management and super-vision of pre-decommissioning activities	PMU Consultant, phase 1	A1.1	BIDSF	10/03 -12/07	
	PMU Consultant, phase 2	A1.2	BIDSF	12/07 -12/11	
1. Separation of V1 NPP from the other SE EBO facilities remaining in operation					
Replacement of services that V1 NPP provides for other installations and facilities at SE EBO site (e.g. heating, process steam, back-up services, safety functions) and provision of new and/or modified services for V1 NPP systems (e.g. water, steam, heating, electricity)	Relocation of emergency response centre	A3-C	BIDSF, [18]	08/06 -06/08	
	Modification (separation) of the power supply system of V1 NPP and V2 NPP and SE VYZ	A5-A	BIDSF, [18]	11/07 -07/12	
	Modification of heating and steam distribution system	A5-B1	BIDSF, [18]	03/06 -02/07	
	Reliable heat and steam supply: Reconstruction of the auxiliary boiler station at the Bohunice site	A5-B2	BIDSF, [18]	04/05 -05/06	
	Modification of cooling and service water systems, and raw water inlet system	A5-C	BIDSF, [18]	01/09 -12/09	
	Replacement of operating fluids of the V1 NPP, V2 NPP and SE VYZ	A5-D	BIDSF, [18]	12/11 -12/12	
Physical separation of V1 NPP from the SE EBO facilities remaining in operation	Reconstruction of area protection system AKOBOJE	A3-A	BIDSF, [18]	03/06 -04/10	
2. Preparation and realisation of V1 NPP final shutdown and termination of operation					
Establishment of a radioactive waste and spent fuel management strategy	Report on Bohunice V1 NPP decommissioning and historical waste management strategy	A1.1 (D8)	BIDSF, [11]	07/04 -07/05	
	Spent fuel management	A5-E	BIDSF	04/06 -12/06	
Development of operating documentation amendments for the operation termination period	Development of comprehensive documentation necessary for V1 NPP decommissioning licensing phase and decommissioning implementation phase	A2.1	BIDSF	06/06 -07/11	
Personnel training for new tasks in connection with operation termination after the final reactor shutdown					

Document V1 NPP Final Conceptual Decommissioning Plan

TIP 7

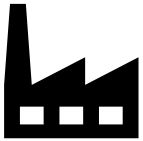
Transition from operation to decommissioning stage is an opportunity to optimize decommissioning supporting operation

Part 4 - Analysis of decommissioning options



Option 1
Immediate Decommissioning Option (IDO)

Immediate and continuous dismantling of facilities and demolition of civil structures.

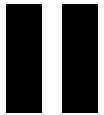


Option 2
Safe Enclosure with 30 years Surveillance (SES)

Safe entombment of ALL ACTIVE FACILITIES and OBJECTS for a period of 30 years.

Option 3
Reactor Safe Enclosure with 30-years surveillance (RSE)

Safe entombment of REACTOR in reactor shaft for a period of 30 years.



Option 4
Zero Option

NO dismantling, NO demolition and NO active parts entombment action(s) after shut down of NPP to be taken. This status to last for an indefinite period.

1. **Application of PSL (Proposed standardized list)**
2. **Development of WBS / comprehensive appraisal per each assessed option**
3. **Relevant parameters calculated based on PSL items in following areas**

- Time sequence of civil buildings decommissioning
- Overall Decommissioning time schedule
- Estimation of labor for each PSL items in implementation period
- Material Flow Estimation
- Investment costs
- CED estimate
- Gaseous and liquid discharges for relevant PSL items

TIP 8

Consider international Lessons Learned, Best Available Techniques and National specifics. It has direct impact on results

No.	Characteristic output parameter	Value	Unit
1	Collective effective dose		manSv
2	Duration of the decommissioning process under the authorisation for decommissioning		year
3	Labour hours needed		10^3 man hr
4	Amount of liquid RAW (before processing at salinity 200 g/dm^3)		m^3
5	Radioactivity of gaseous effluents		Bq
6	Radioactivity of liquid effluents		Bq
7	Amount of released metals		t
8	Amount of recyclable building waste		t
9	Amount of communal waste		t
10	Number of FCC for NSR (Near Surface Repository)		FCC (*)
11	Number of FCC for IS RAW (Interim Storage of Radioactive Waste)		FCC (*)
12	Time load of site by radioactivity		year

(*) FCC: Fibre Concrete Container

Part 5 - Cost estimation and financial arrangements

Application of PSL (Proposed standardized list) items for costing purposes in decommissioning of nuclear facilities – document of IAEA and OECD/NEA, 1999 (now ISDC)

1

Calculation of cost for individual psl items based on following structure:

- Labor costs
- Overhead costs
- Investment costs
- Contingency

2

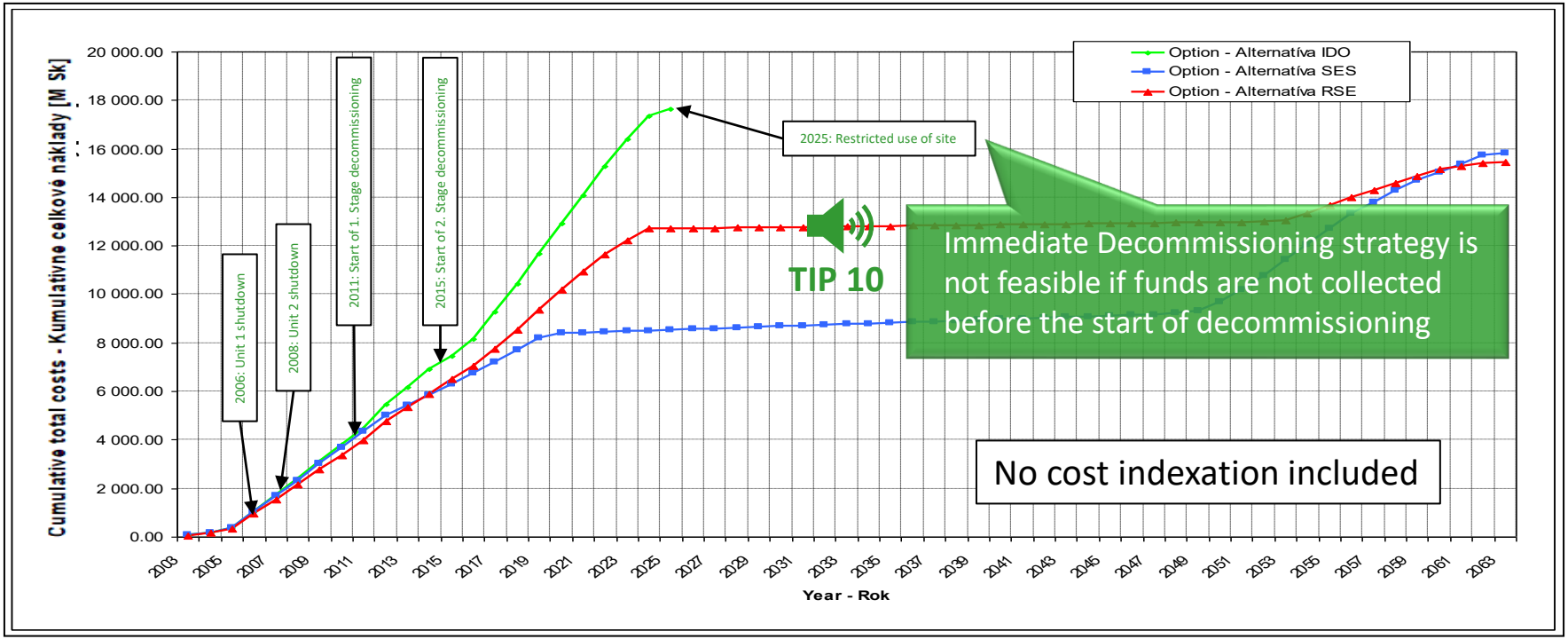
Costs sensitivity analysis in relation to

- Unit labor costs – most sensitive factor
- Unit overhead costs
- Unit prices of consumer costs

TIP 9

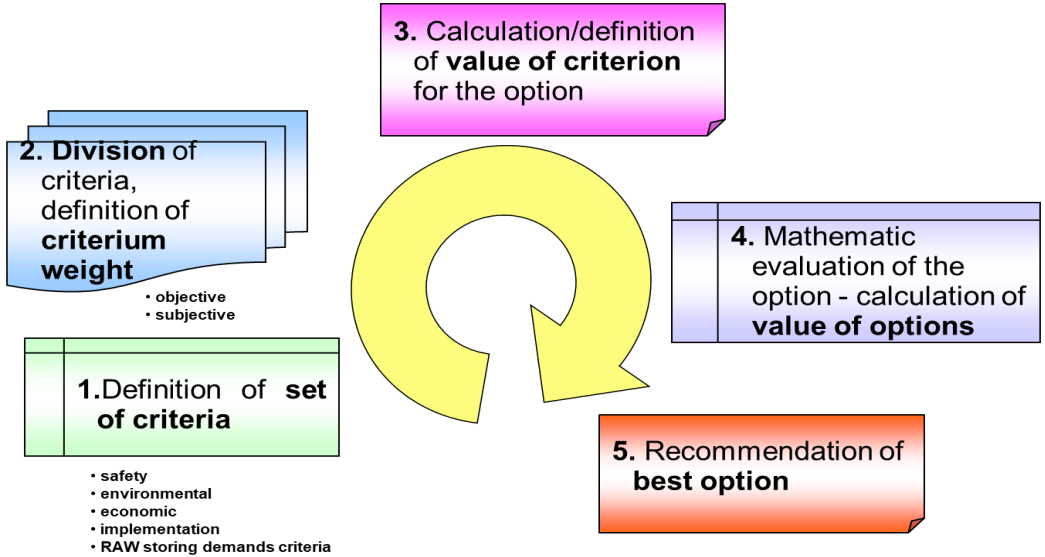
Take advantage of software to optimize decommissioning cost calculation and display results in ISDC International Structure for Decommissioning Costing

Time distribution of decommissioning costs in years (Cumulative values in time) per alternative



Part 6 - Complex comparison of decommissioning options - MCA utilization

Scheme of multi-criterial analysis



OBJECTIVE Criteria (Value of criterion specificized by the calculation)
SUBJECTIVE Criteria (VALUE of criterion specificized by an expert estimate)

Set of evaluation criteria, their division into groups and classes and determination of criterion weight

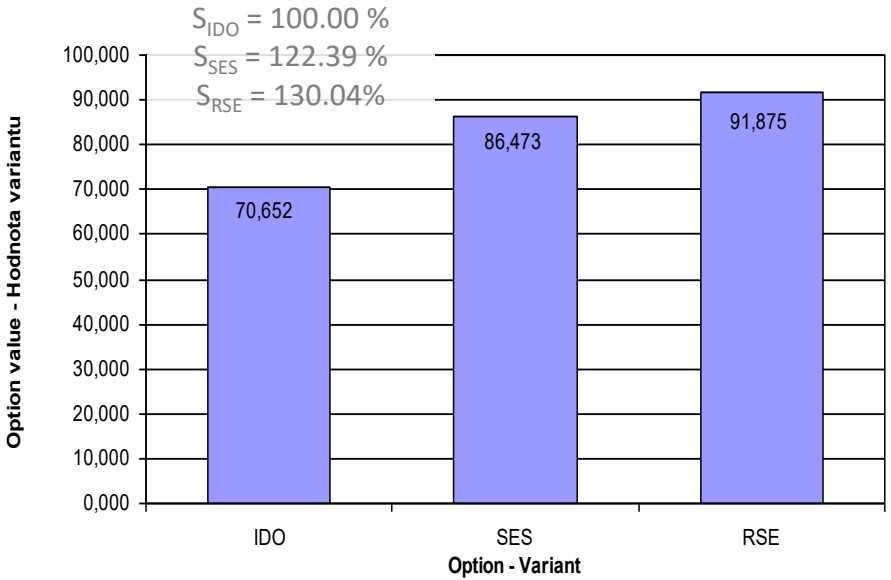
No.	Description	Criterion weight	Criterion class
	Safety criteria		
1	Total CED	10	Objective
	Environmental criteria		
2	Radiation consequences of gaseous effluents to environment	5	Objective
3	Radiation consequences of liquid effluents to environment	5	Objective
4	Time load of site by radioactivity	6	Objective
5	Amount of conventional waste	2	Objective
	Economic criteria		
6	Total costs	8	Objective
7	Time distribution of costs	8	Subjective
8	Labour hours needed	5	Objective
	Implementation criteria		
9	Continuity of manpower and RAW processing facilities utilisation	8	Subjective
10	Time of final site release	7	Objective
11	Preparedness of site for further utilisation	3	Subjective
	Criteria of demands for RAW repositories		
12	Total number of FCC into NSR	8	Objective
13	Total number of FCC into ISRAW	8	Objective

Final results of multi-criterial analysis - the principle "the lowest is the most suitable"

No.	Description	Contribution of criterion to option value		
		IDO	SES	RSE
	Safety criteria			
1	Total CED	11.799	6.949	11.251
	Environmental criteria			
2	Radiation consequences of gaseous effluents to environment	5.662	3.587	5.750
3	Radiation consequences of liquid effluents to environment	5.655	3.590	5.755
4	Time load of site by radioactivity	2.131	7.934	7.934
5	Amount of conventional 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	Labour hours needed	5.442	4.889	4.669
	Implementation criteria			
9	Continuity of manpower and RAW processing facilities utilisation	4.235	11.294	8.471
10	Time of final site release	2.492	9.254	9.254
11	Preparedness of site for further utilisation	1.000	4.000	4.000
	Criteria of demands for RAW repositories			
12	Total number of FCC into NSR	8.377	7.150	8.473
13	Total number of FCC into ISRAW	10.154	6.923	6.923
	Option value - S_j	**70.651**	**86.473**	**91.875**

Part 7 - Conclusion

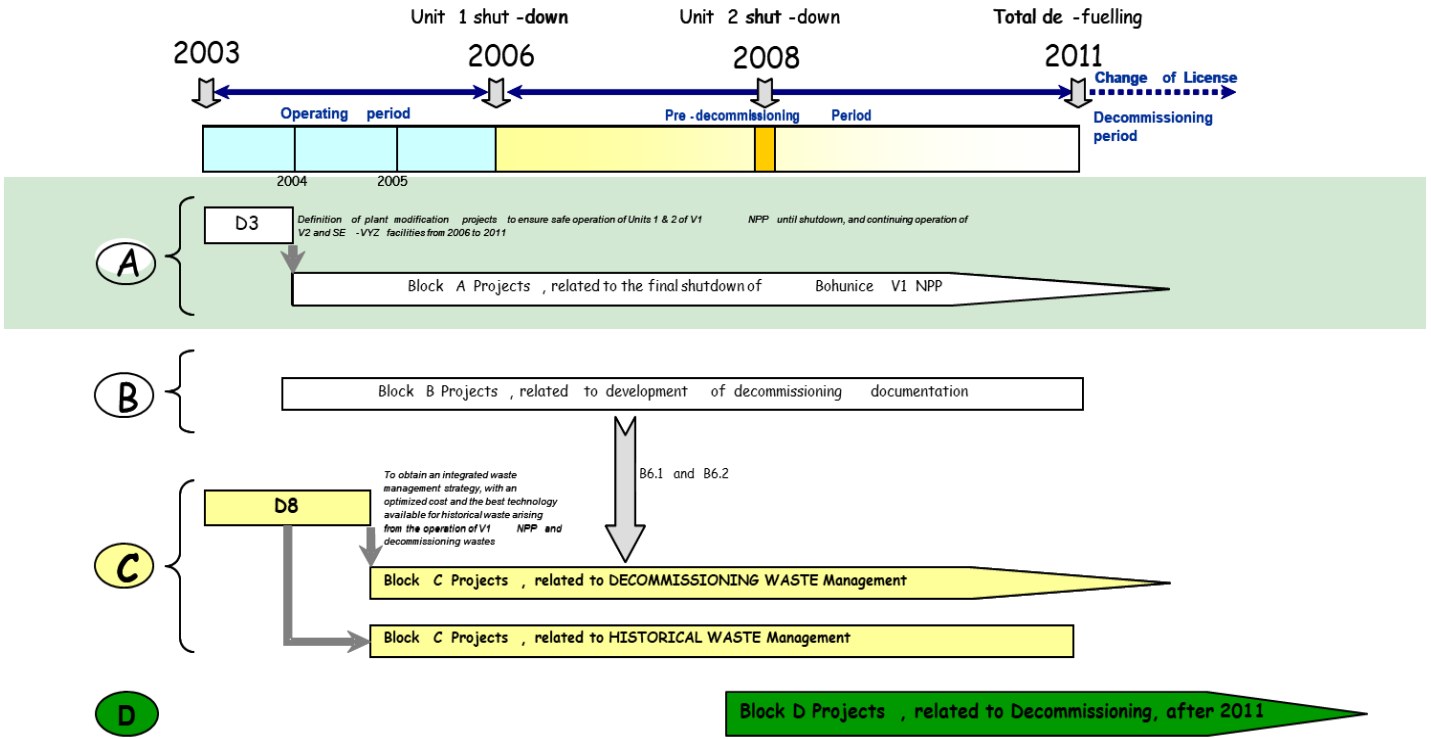
Final results of multi-criterial analysis - the principle “the lowest is the most suitable”



The selection of the most suitable V1 NPP **decommissioning option** based on the multi-criterial comparison of the analyzed options **had character of recommendation only.**

The final and real selection of V1 NPP decommissioning option was made later, based on the FCDP and the **EIA report development** in accordance with Act No. 127/1994 Coll. and of its **submission to / appraisal by the Slovak Ministry of Environment.**

Assignment of decommissioning activities to decommissioning projects



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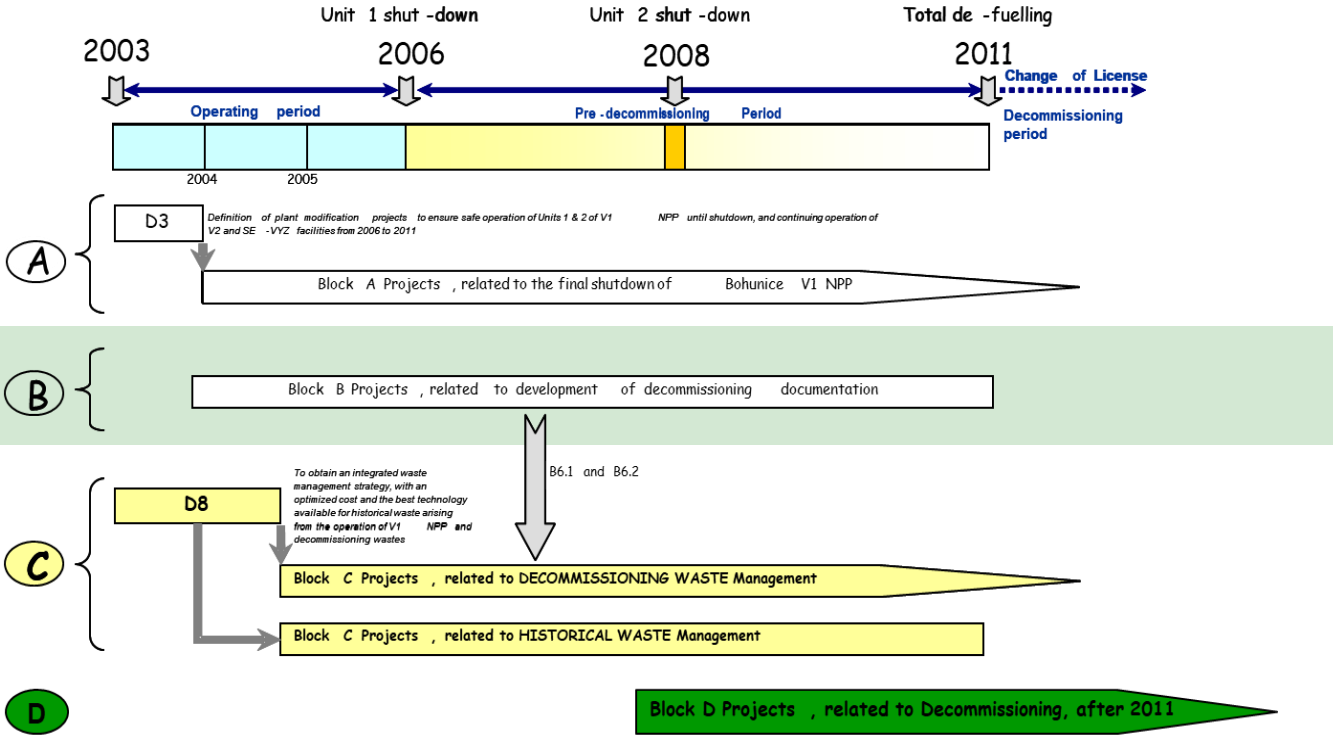

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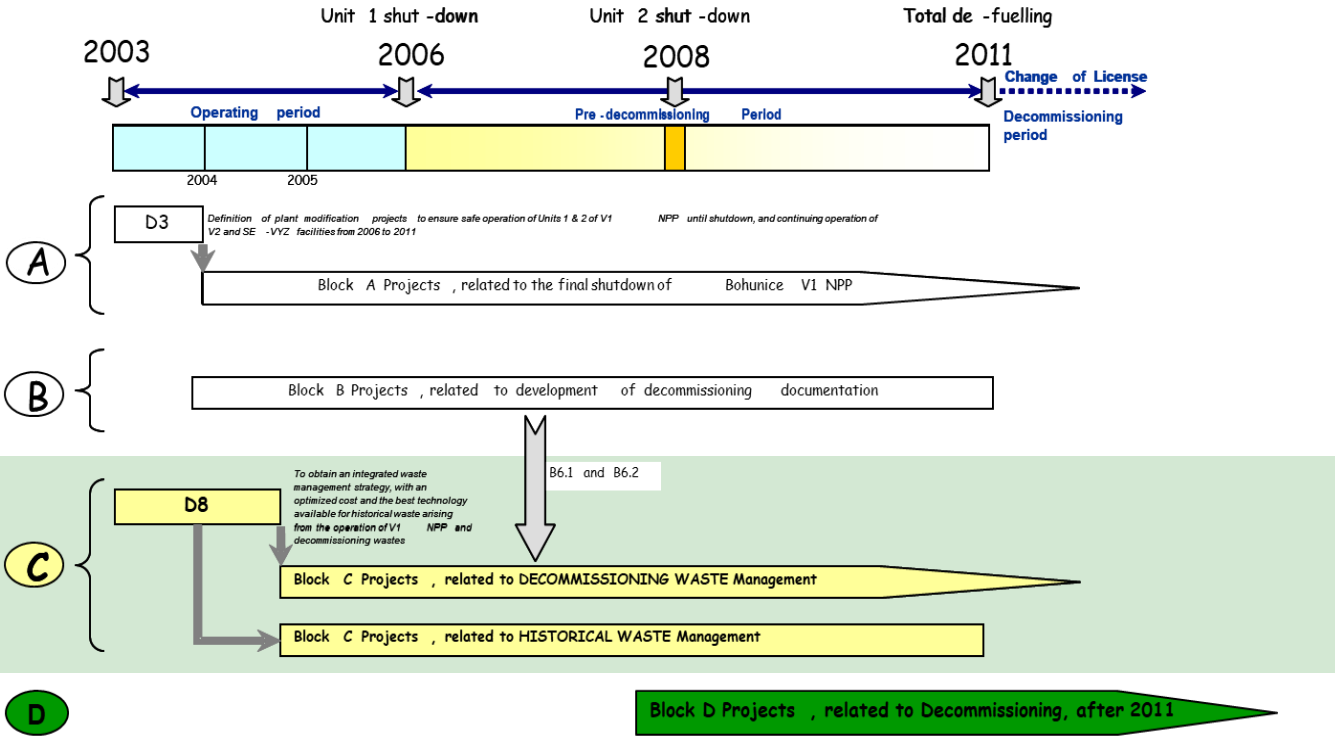

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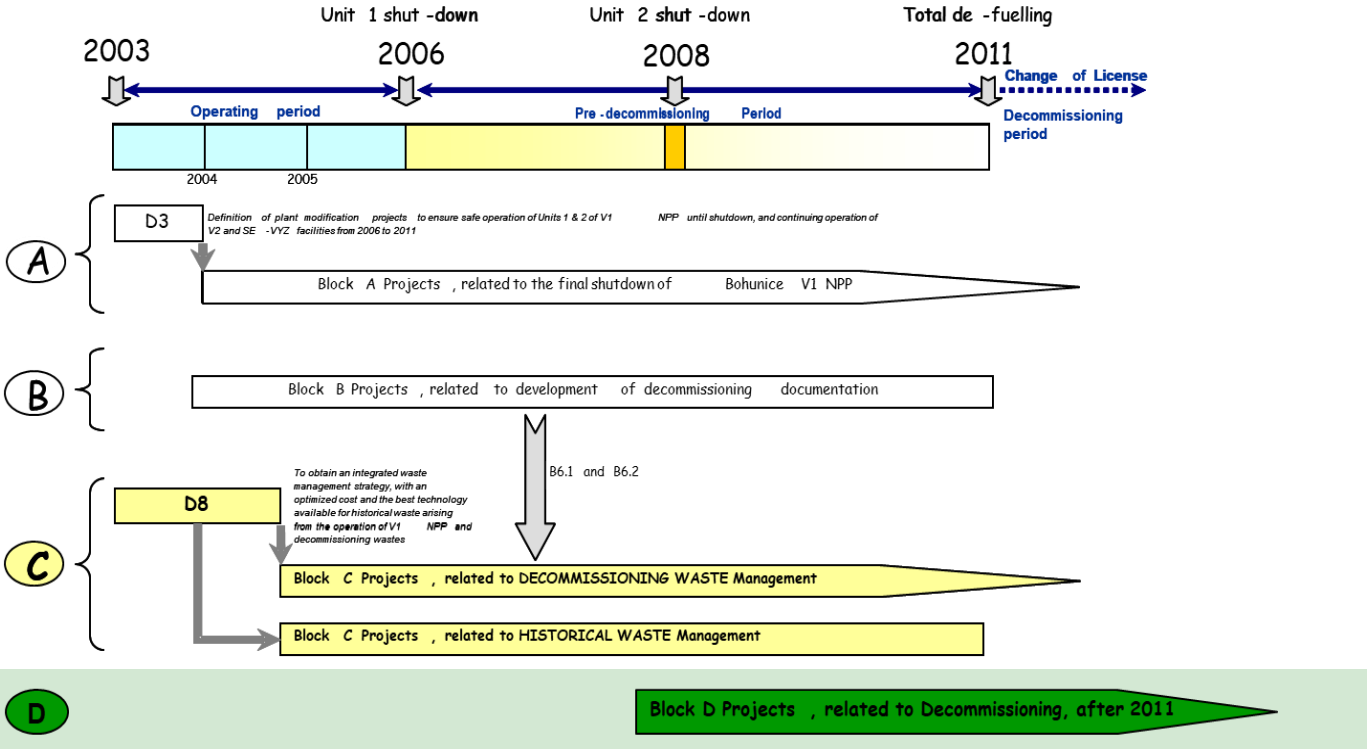
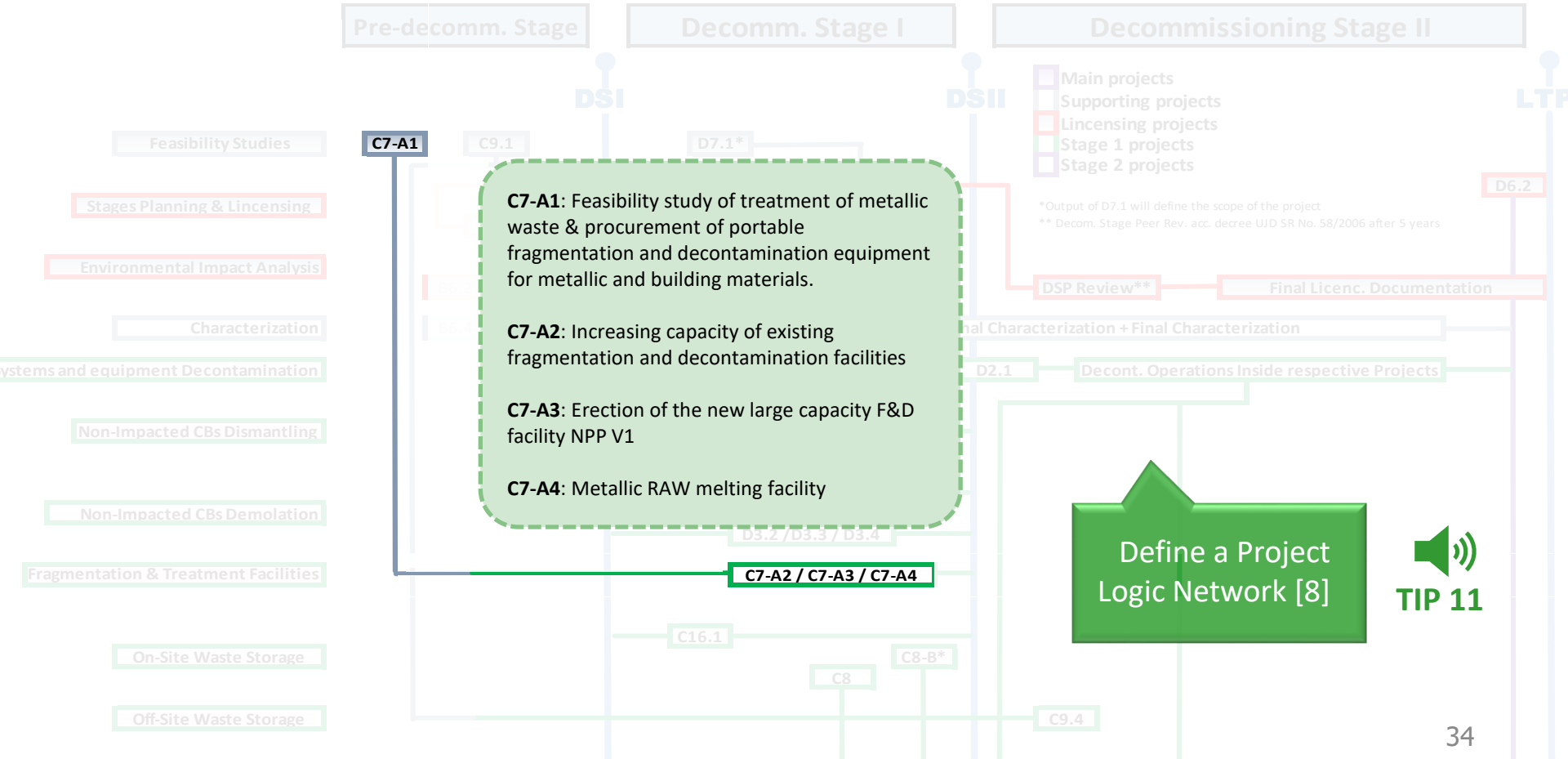


Assignment of decommissioning activities to decommissioning projects

Sufficient projects` scope set-up results in:

- Coverage of all relevant activities
- Reduction of uncertainties /risks
- Increase of project implementation efficiency (exact scope)
- Project Cost reduction
- Effective time/interface schedule
- Easy management and monitoring of projects

6. Conceptual set-up of the decommissioning projects (blocks from „A“ to „D“)



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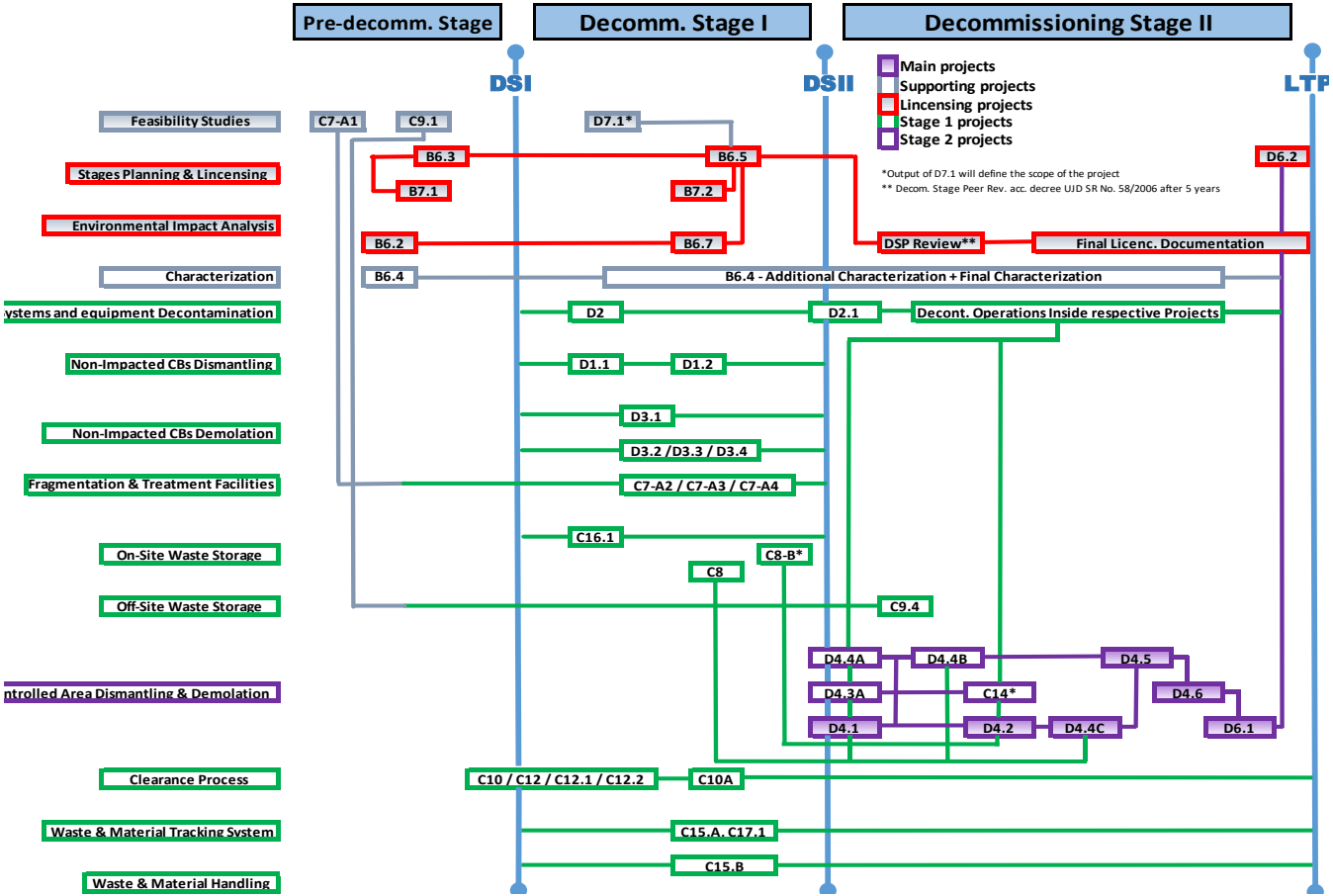
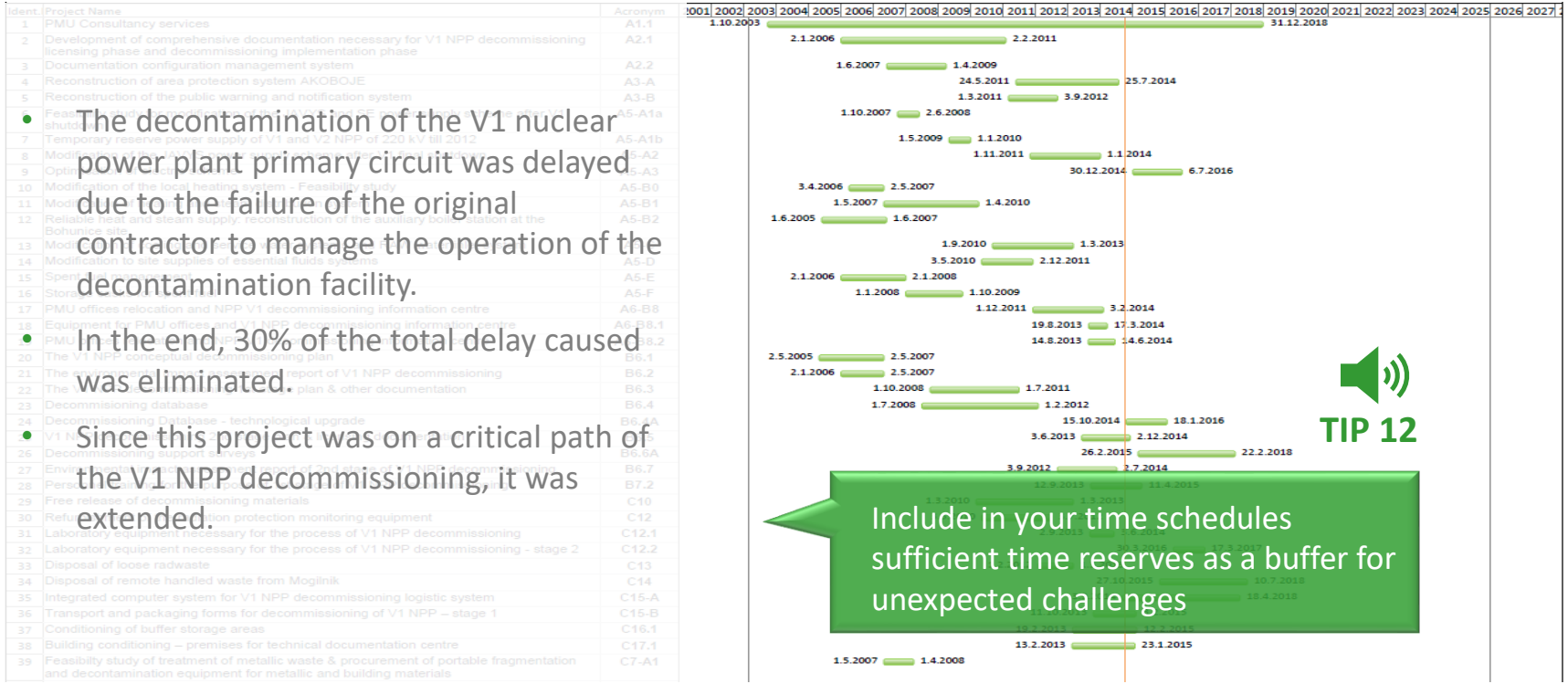


Example of whole V1 NPP Implementation Time Schedule – simplified version [8]

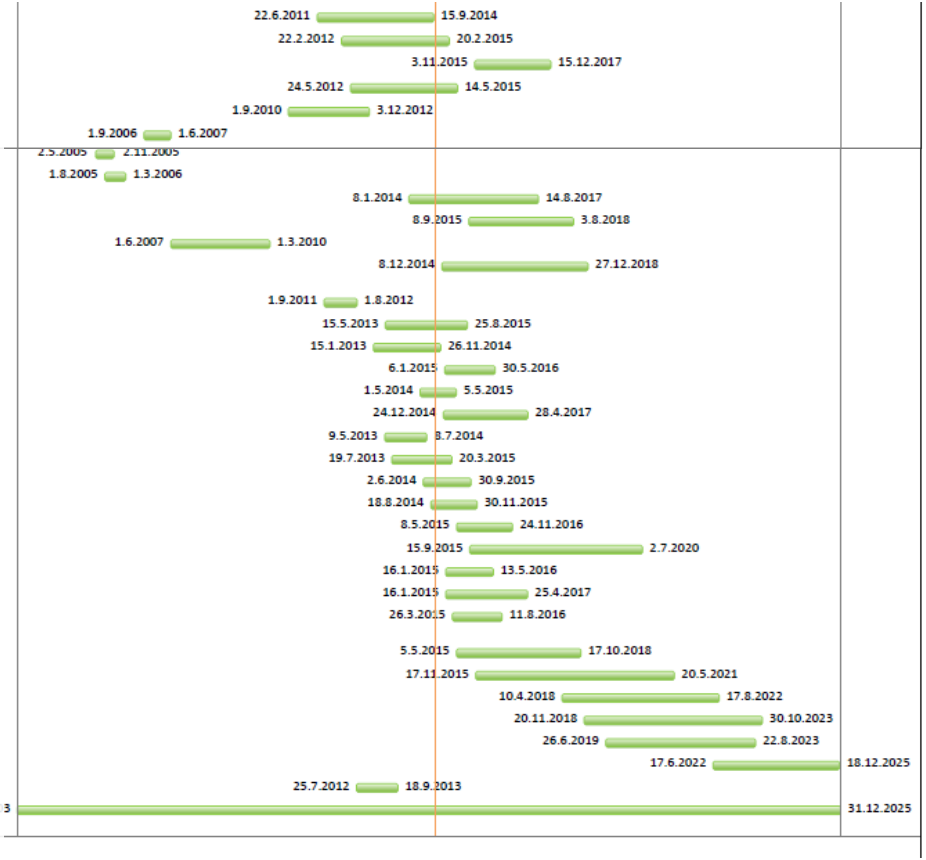
- The decontamination of the V1 nuclear power plant primary circuit was delayed due to the failure of the original contractor to manage the operation of the decontamination facility.
- In the end, 30% of the total delay caused was eliminated.
- Since this project was on a critical path of the V1 NPP decommissioning, it was extended.



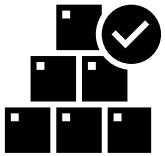
6. Conceptual set-up of the decommissioning projects (blocks from „A“ to „D“)

Application of new, not yet tested technologies, always carry the risk of delays.

- A conceptually new fragmentation facility was built for the fragmentation of steam generators.
- The first steam generator was fragmented in about 13 months. After testing and adjusting of the fragmentation facility other steam generators were fragmented in about 3 months.
- Regarding Radioactive waste processing, a decommissioning database was prepared with high accuracy. Even so, a larger amount of radioactive waste was processed.
- This may have a negative impact on the original planning of radioactive waste processing capacities and may suspend dismantling activities in the controlled area. In order to eliminate these uncertainties, buffer storages were built, which will store these unexpected quantities of radioactive waste until they are processed.

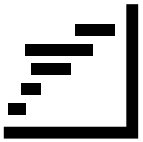


7. Conclusions

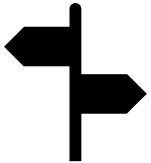


Selection
to apply Multi-criterial analysis, during selection of an optimal decommissioning alternative.

RAW preparation
to apply road map for preparation / set up of waste management system



Scope
to learn how to optimize the scope of the decommissioning projects and their time of implementation



Transition
to consider changes in Radiological Risk Profile during the transition from operation to decommissioning with aim to optimize nuclear facility operation

Costing
to learn about International structure for decommissioning costing - ISDC utilization

Logic Network
to use V1 NPP Decommissioning Project Logic Network as example of the first level of decommissioning activities WBS

8. Value

1

This Knowledge Product, “The Bohunice V1 NPP Final Conceptual Decommissioning Plan“ (FCDP) provides end users with valuable knowledge which can help (especially during the FCDP preparation):

- **Reduce uncertainties** in decommissioning activities (better risks mitigation)
- **Save costs** based on existing synergies gained from similar projects
- Improve nuclear, radiation and industrial **safety** in planned projects implementation

2

The gained knowledge can provide to the end users tools for optimization of their decommissioning activities thus deliver the higher level of efficiency and self sustainability as well.

9. Abbreviations

A1 NPP	Nuclear Power Plant A1
B6.1	BIDSF project “The V1 NPP Conceptual Decommissioning Plan ”
B6.2	BIDSF project “The Environmental Impact Assessment Report of V1 NPP Decommissioning ”
B6.3	BIDSF project “The V1 NPP Decommissioning 1st Stage Plan & Other Documentation ”
B6.4	BIDSF project “Decommisioning database ”
B7.1	BIDSF project “Personel trainings/education"
BIDSF	Bohunice International Decommissioning Supporting Fund
CDP	Conceptual Decommissioning Plan
CED	Collective Effective Dose
C10A	Free Release of Decommissioning Materials
DDB	Decommissioning Database
DGR	Deep Geological Repository
EC	European Commission
EIA	Environmental Impact Assessment
FCC	Fibre Concrete Container
FCDP	Final Conceptual Decommissioning Plan
IAEA	International Atomic Energy Agency
IDO	Immediate Decommissioning Option
IS RAW	Interim Storage of Radioactive Waste
ISDC	International Structure for Decommissioning Costing
JAVYS, Plc	Nuclear and Decommissioning company
KP1	Knowledge Product No.1
MCA	Multi-criterial Analysis
NNF SR	National Nuclear Fund of Slovakia
NSR	Near Surface Repository
OECD/NEA	Organisation for Economic Co-operation and Development / Nuclear Energy Agency
OMEGA	Sophisticated software for decommissioning costing
PSL	Proposed Standardised List
Ra	Radioactive
RAW	Radioactive Waste
RCM	Radioactively Contaminated Materials
RSE	Reactor Safe Enclosure
RWM	Radioactive Waste Management
SES	Safe Enclosure Surveillance
SF	Spent Fuel
V1 NPP	Nuclear Power Plant V1
WBS	Work Breakdown Structure

10. References

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[2] Presentation on Decommissioning scenarios Analysis, Worldwide NPP decommissioning program analysis and prognosis, Mr Christian GLORENNEC IAEA Vienna 2018

[3] V1 NPP Decommissioning Documentation – first stage: Project B6.1 – "The V1 NPP Conceptual Decommissioning Plan"

[4] 541/2004 Collection of Laws, ACT of 9 September 2004 on peaceful use nuclear energy (the Atomic Act) and on changes and amendments to certain laws

[5] National Programme for the Management of Spent Nuclear Fuel and Radioactive Waste in the Slovak Republic, National Nuclear Fund of Slovakia

[6] D3-TD-PMU-05004, PRE-DECOMMISSIONING PACKAGE CONCEPTUAL ENGINEERING OF THE PHYSICAL MODIFICATIONS

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[9] Detailed Decommissioning Plan of V1 NPP (2014)

THANK YOU FOR YOUR ATTENTION