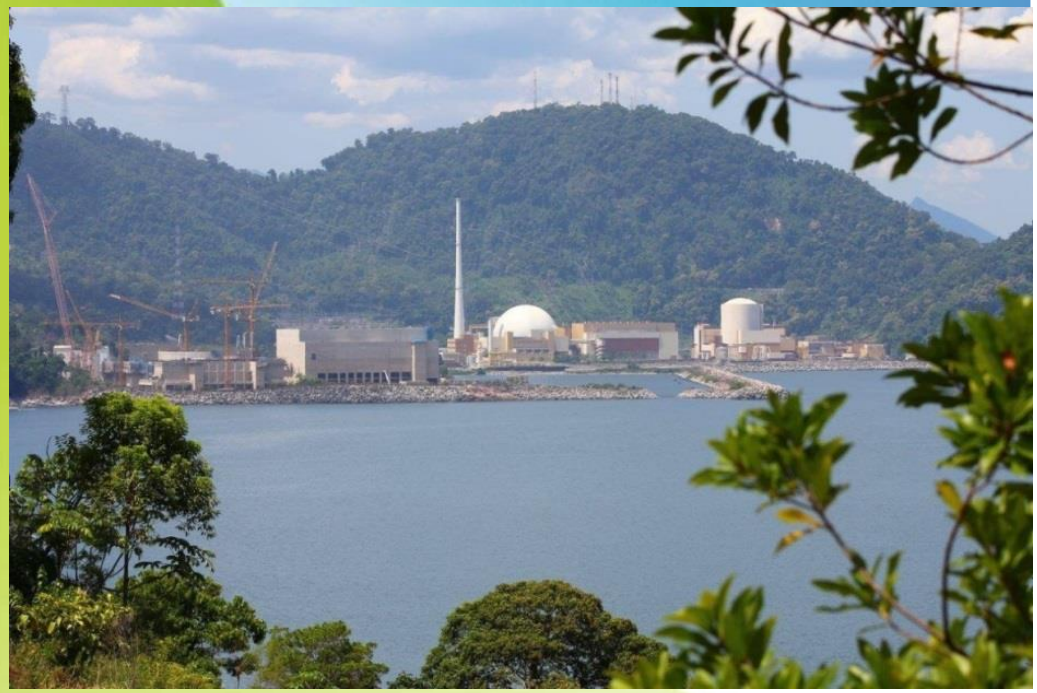
Proposal for an Initial Plan for the Transition Period from Permanent Shutdown of a nuclear power plant type Angra 1 until the Condition of Safe Storage - N08-029



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VI Encontro da Industria Nuclear – VI ENIN

October 2019

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1.1 Objective

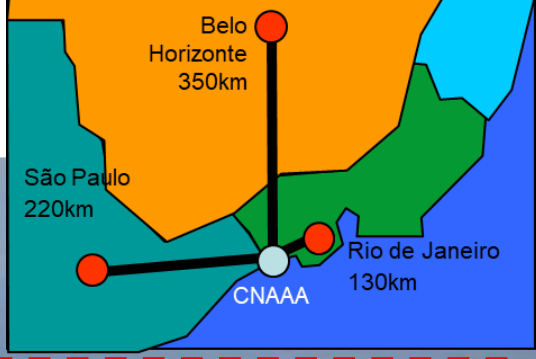
- ✓ To **prepare** an **initial plan for Angra 1 NPP** to go through its Reactor Transition Period (TPA1), from its **Reactor Permanent Shutdown** to **Safe Storage condition**, **IDENTIFYING THE MOST RELEVANT ISSUES**, to be executed successfully, on time and cost, within the SAFETY STANDARDS based on **REFERENCES AND INTERNATIONAL EXPERIENCE**.

- ✓ Fulfill a **gap** of the **PDP** of CNAAA site.

- ✓ **Reasons** for **Delay and Problems / Financial Loss** during TP (IAEA, 2004):
  - ► Unavailability of funds; ► Early, unplanned and PS - political, regulatory or economic reasons;
  - ► Lack of a decommissioning strategy;
  - ► Lack of infrastructure (Intermediate or Final Repository) or technology;
  - ► RW characterization and disposal; ► Lack of regulation;
  - ► Loss / demotivation of key people = cultural changes;
  - ► Lack of planning for decommissioning during plant operation

Mitigate these factors >>>> Early Planning

1.2 Almirante Álvaro Alberto Nuclear Center CNAAA



ANGRA 1 PWR
Power: 640 MW
Technology: Westinghouse
Operation start: Jan. 1985

ANGRA 2 PWR
Power: 1,350 MW
Technology: KWU/ Siemens
Operation start: Jan. 2001

ANGRA 3 PWR
Power: 1,405 MW
Technology: KWU/ Siemens - Framatome
Civil works reached ~67 %.

(illustrative view)

ANGRA 1

ANGRA 2

RADIOACTIVE WASTE STORAGE CENTER

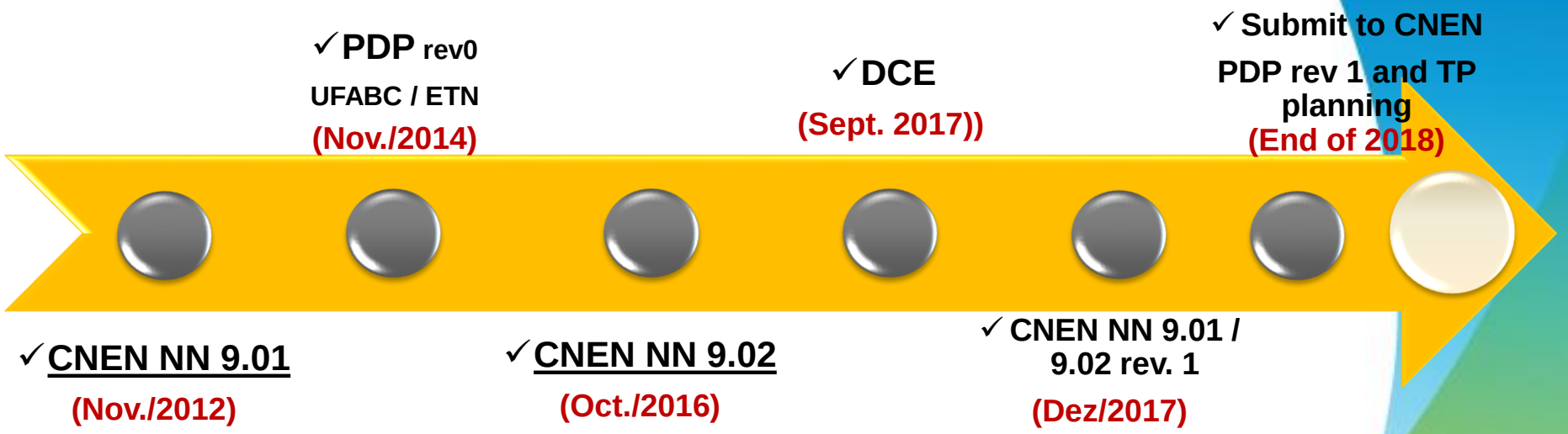
500kV Switchyard

Waste Monit. Building – New
Civil works – 95%

UAS (ISFSI) – 2020

Illustrative picture

1.3. Chronology of Licensing in Brazil



✓ **CNEN-NN-9.01 – DECOMMISSIONING OF NPPs (2012): BASIC REQUIREMENTS OF NUCLEAR SAFETY** to be achieved on **PLANNING / IMPLEMENTATION OF DECOMMISSIONING**

✓ **CNEN-NN-9.02 – MANAGEMENT OF FINANCIAL RESOURCES FOR DECOMMISSIONING OF NPPs (2016): DTF GUARANTEE WITH ANNUAL REPORTS, AUDITS AND ACTUARIAL CALCULATION SPECIFIC METHOD/REPORT.**

- ❑ Rev. Dez/2017 >>>>> + ETN > SFA and RW management
- ❑ CNEN Req. May/2018 >> + Transition Period Planning

1.4. Decommissioning in Brazil

- **DECOMMISSIONING:** ***Administrative and technical actions to allow the removal of some or all of the regulatory controls from a facility*** ***(CNEN NN 9.01, 2012)***

With no unacceptable risk to the public, the workers and the environment

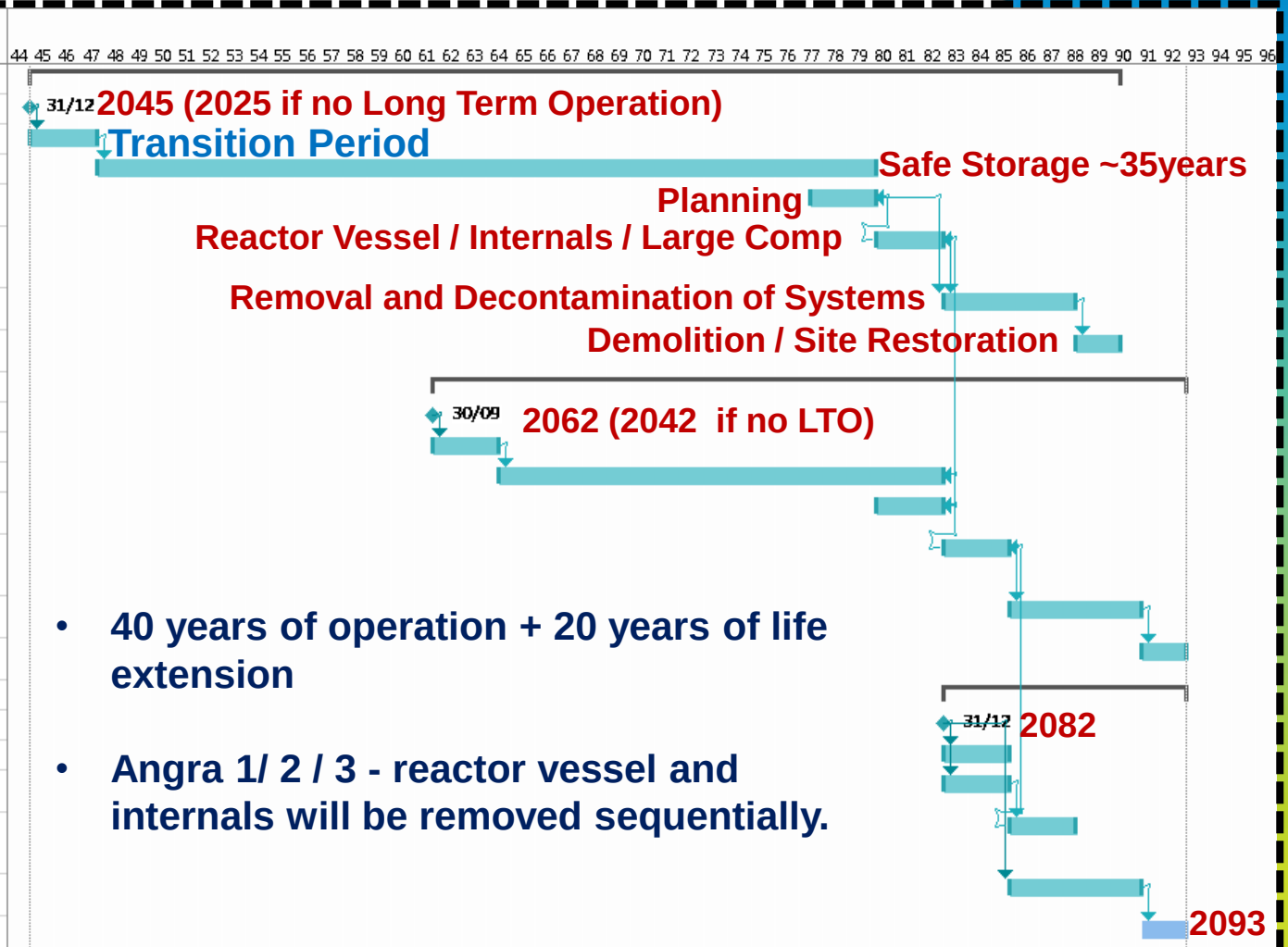
- **Decommissioning Strategy for CNAAA:**

  - ❑ **Deferred Dismantling: Angra 1 and 2 NPPs**
  - ❑ **Immediate Dismantling: Angra 3 NPP**

- **Desired End State – Unrestricted use**

1.5. Preliminary Decommissioning Plan CNAAA - Summary Schedule

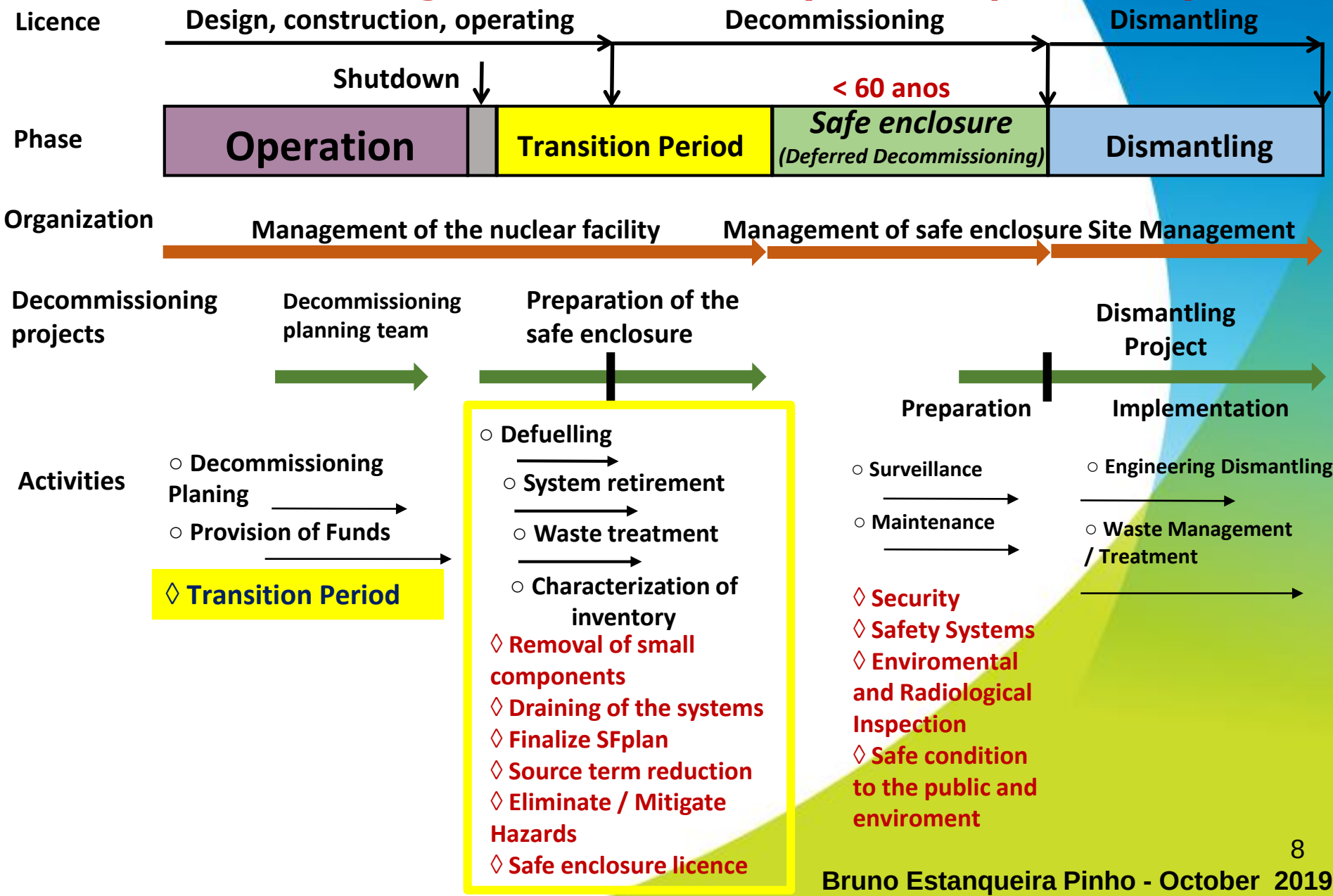
Id	Task Name	Duração	Início	Término
1	**Angra 1**	11833 dias	Sáb 31/12/44	Qua 10/05/90
2	Plant Shutdown	0 dias	Sáb 31/12/44	Sáb 31/12/44
3	Transition Period	36 meses	Seg 02/01/45	Sex 04/10/47
4	Safe Storage Period	423,75 mes	Seg 07/10/47	Sex 29/03/80
5	Decommissioning Planning	36 meses	Qui 24/06/77	Qua 27/03/80
6	Remove Reactor Internals, Vessel, Large Components	36 meses	Qui 28/03/80	Qua 30/12/82
7	Remove Systems & Decontamination	72 meses	Qui 31/12/82	Qua 07/07/88
8	Demolition & Site Restoration	24 meses	Qui 08/07/88	Qua 10/05/90
9	**Angra 2**	8184 dias	Sex 30/09/61	Qua 11/02/93
10	Plant Shutdown	0 dias	Sex 30/09/61	Sex 30/09/61
11	Transition Period	36 meses	Sex 30/09/61	Qui 03/07/64
12	Safe Storage Period	241,4 mes	Ter 01/07/64	Qui 31/12/82
13	Decommissioning Planning	36 meses	Qui 28/03/80	Qua 30/12/82
14	Remove Reactor Internals, Vessel, Large Components	36 meses	Qui 31/12/82	Qua 03/10/85
15	Remove Systems & Decontamination	72 meses	Qui 04/10/85	Qua 11/04/91
16	Demolition & Site Restoration	24 meses	Qui 12/04/91	Qua 11/02/93
17	**Angra 3**	2640 dias	Qui 31/12/82	Qua 11/02/93
18	Plant Shutdown	0 dias	Qui 31/12/82	Qui 31/12/82
19	Transition Period	36 meses	Qui 31/12/82	Qua 03/10/85
20	Decommissioning Planning	36 meses	Qui 31/12/82	Qua 03/10/85
21	Remove Reactor Internals, Vessel, Large Components	36 meses	Qui 04/10/85	Qua 07/07/88
22	Remove Systems & Decontamination	72 meses	Qui 04/10/85	Qua 11/04/91
23	Demolition & Site Restoration	24 meses	Qui 12/04/91	Qua 11/02/93



- 40 years of operation + 20 years of life extension
- Angra 1/ 2 / 3 - reactor vessel and internals will be removed sequentially.

1.6. Transition Period

Decommissioning Related Activities (IAEA adapted 2004)



1.7. Decommissioning in World

Shutdown reactors in World (WNA, 2019)

Shutdown reactor motive	Country / Region	**EUROPA**	**EUA**	Russia	Japan / South Korea	Canada	Total
Shut down reactors that have fulfilled their purpose or are no longer economically viable	qty	**62**	**32**	7	14	4	119
Reactors shut down prematurely for political reasons	qty	**34**	**1**	0	2	0	37
Total	qty	**96**	**33**	7	16	4	156

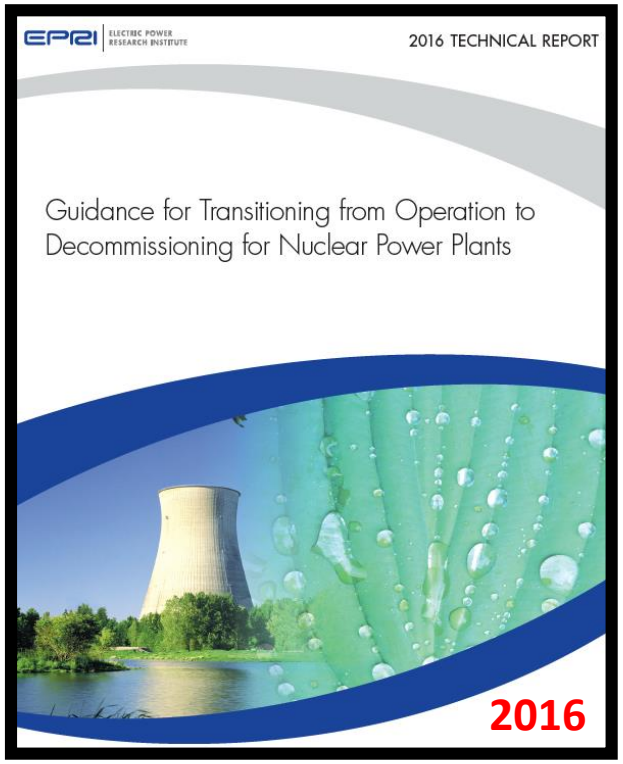
~24%

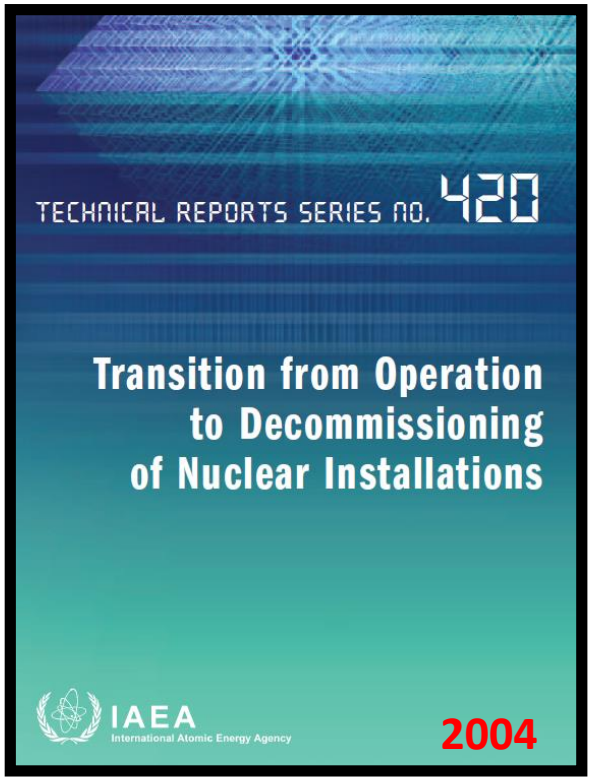
Not considered those shutdown after accidents

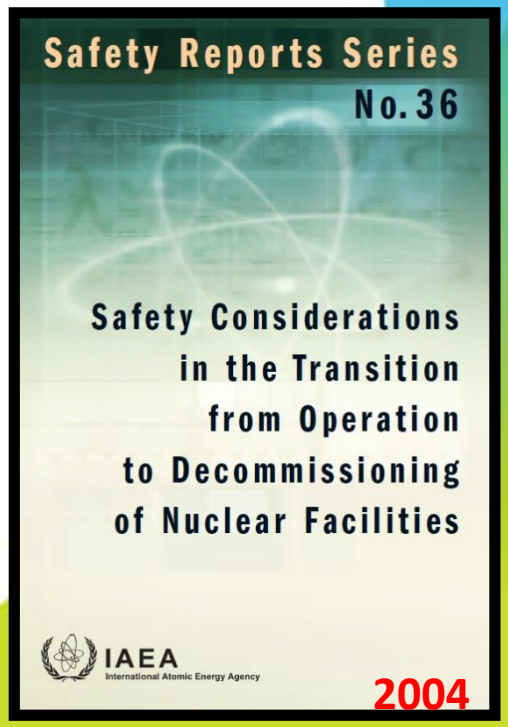
~84,2%

✓**EPRI / NRC + IAEA + International References**

1.8. Transition Period Planning - EPRI + IAEA + Referencies







+ Lessons Learned

+ Other References

8.I Table of Contents of Angra 1 Transition Period Plan

1. Licencing
2. Human Resources and Organizational Struture
3. Communication Plan
4. Historical Site Assessment(HSA) e RW Characterization
5. Chemmical Decontamination of Systems
6. Cool and Dim planning
7. Removal of Inflamable material and transition to a Incipient Fire Brigade (IFB)
8. Spent Fuel Management
9. Removal and Reduction of Hotspots
10. Dismantling of systems and non radioactive buildings
11. Removal / retirement of systems and review of technical specifications
12. Safety Assessment for the TP
13. Summary of Activities for the NPP
14. Cost Estimate for Transition Pertiod – order of magnitude
15. Quality Plan and Administrative Controls

8.II - Licensing – Transition Period - Brazil

NO SPECIFIC STANDARDS FOR THE TRANSITION PERIOD IN BRAZIL

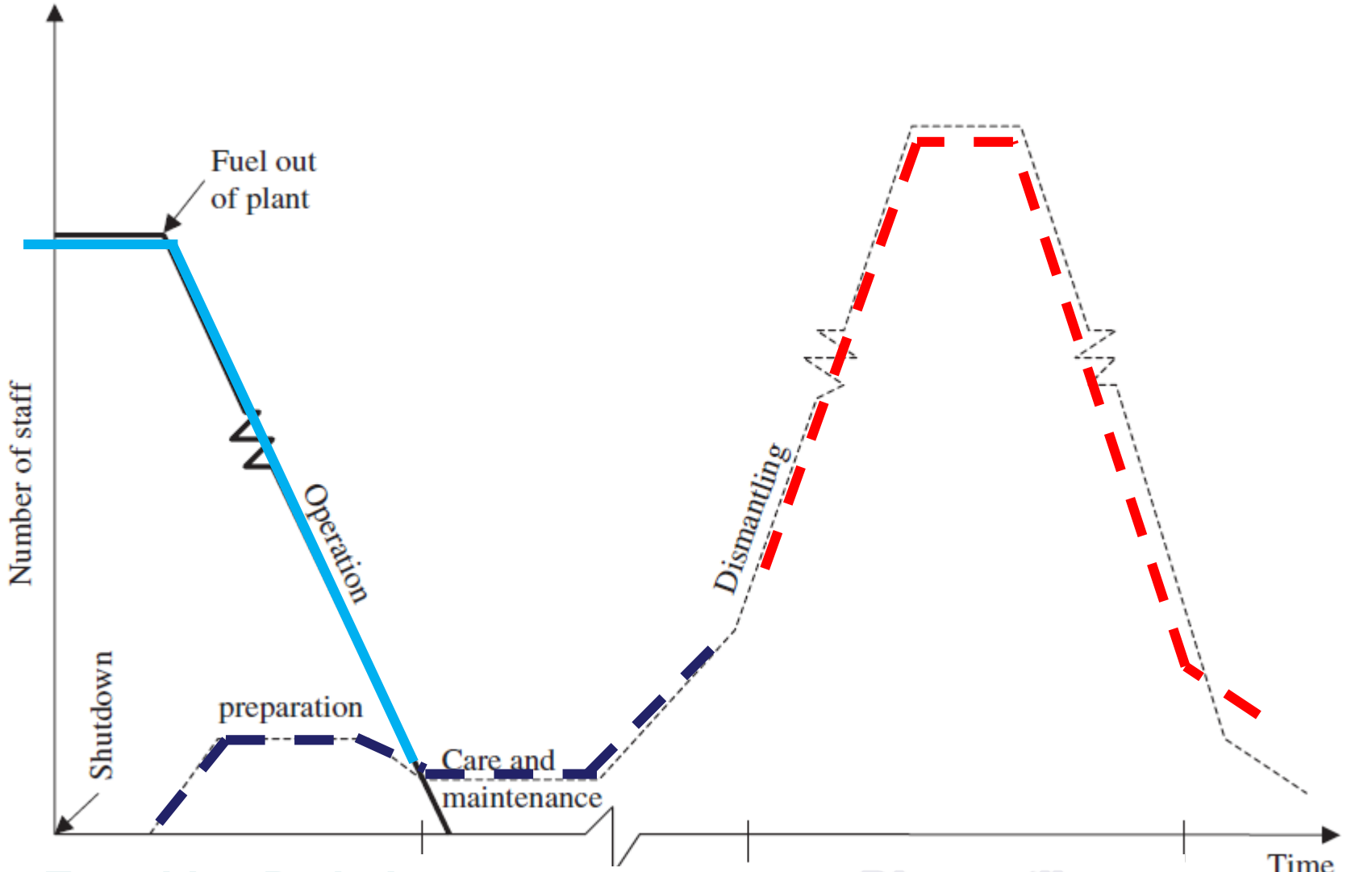
Assumption >>> NRC format / Main documents

1. Certificate of Permanent Termination of Operation and Removal of SFA
2. Post shutdown decommissioning activities report (PSDAR)
3. Review of the DCE and Transition Period Costs

CNEN Req. Res. 217/218

4. Irradiated Fuel Management Plan (IFMP)
5. License Termination Plan (LTP)
6. Post Defueled Technical Specifications Request (PDTS)
7. Permanent Shutdown Emergency Plan (PSEP)
8. Physical Protection Plan for Permanent Shutdown and Exception Requests
9. Prepare a Quality Management Plan without SFAs
10. Requalification Program for Operators / Fuel Handling Training and Certification Program (CFH)
11. Request exclusions from the nuclear insurance policy
12. Specific Safety Analysis for the Transition Activities
13. FSAR review considering permanent shutdown

8. III - Human Resources - Transition Period staff (IAEA adapted)



8. III - Human Resources - Transition Period

3 PHASES

END OF OPERATIONS

- Need of an independent departament for TP managemant>> growing with time >> Hybrid organizational structure
- Change/transfer of staff (A1 >> A2 >>A3)
- Knowledge management
- Expert consultancy
- Motiviational mechanisms for the staff – prepare for changes
- Bonus for remanining staff - motivation > Keep safety
- Trainning
- Carrer advisory

TRANSITION

- Hybrid organizational structure>> Focus on TP activities
- Staff retention plans and retirement

SAFE STORAGE

- Safe Storage organizational structure
- Special maintenance staff for Angra 1
- Keep NPP in safety during Safe Storage

-5 years earlier | *PERMANENT SHUTDOWN* | *3-5 years* | *End of TP*

Reducing Staff

8.IV - Communication Plan

Communication Management is very important!

>> Lessons Learned > Critical and Essential to**:**

- ✓ Ensure that **project information is well planned, collected, generated, distributed, stored, retrieved, managed, controlled, monitored** and finally **arranged in a timely and appropriate manner**;
- ✓ **Identification of stakeholders** of the project;
- ✓ Increase **public and employees understanding of the activities** to be done to **minimize concern** and **gain support**;
- ✓ Provide **communication support to the project planning** and during the **workforce transition to a decommissioning organization**;
- ✓ Ensure **clear and honest communication**, avoiding gossips and misunderstandings.

8.V - Site History Assessment (HSA) and Initial Characterization

- ✓ **Records of the NPP leakages and contamination** >> History Assessment reliable >> (ALARA) >> **Rad. Prot. Plan**
- ✓ **Risk and Hazard assessment of activities**. RP staff will have to have strong effort to keep the doses ALARA
- ✓ Areas not **usually accessed during normal operations will be accessed**.
- ✓ RW Management and its strategy must be well organized according to the available storages or repositories for RW and SF.
- ✓ Map the hazards material >> remediated and disposed, and make a **Non-radiological HSA**.

8.VI - Chemical Decontamination of Systems and Equipment

- ✓ **Reduce dose rate** and **minimize** the workers **exposure.**
- ✓ **Suggested to be deferred** as it will have a delayed decommissioning to **allow radionuclides decay**
- ✓ **Cost benefit** to be done >> **Maintenance and Surveillance** during **Safe Storage** Period.
- ✓ In the future, if **Angra 1 NPP decides for immediate dismantling**, the **CD** will have to be performed.

8.VII - Conditions for Cool and Dim or Cold and Dark

- ✓ Both to **reduce risks** associated to functioning systems, **deenergizing, depressurizing, and draining all systems** of the plant that are no longer needed for decommissioning **and repowering select systems required for decommissioning**.

- ✓ For Angra 1 NPP >> **Cool and Dim** suggested >> not all systems will be stopped and some systems important to allow safety and work conditions are left energized as **ventilation, radiation monitoring systems** etc

8.VIII - Removal of Flammable Materials and Transition to Incipient Fire Brigade (IFB)

- ✓ **Important to reduce the fire accidents risks** >> Request an IFB where a **lower fire accidents risks is demonstrated to reduce the required fire brigade** and **reduce costs** after Permanent Shutdown (PS).

- ✓ This task will have to be performed some years earlier, during TPA1 detailed planning.

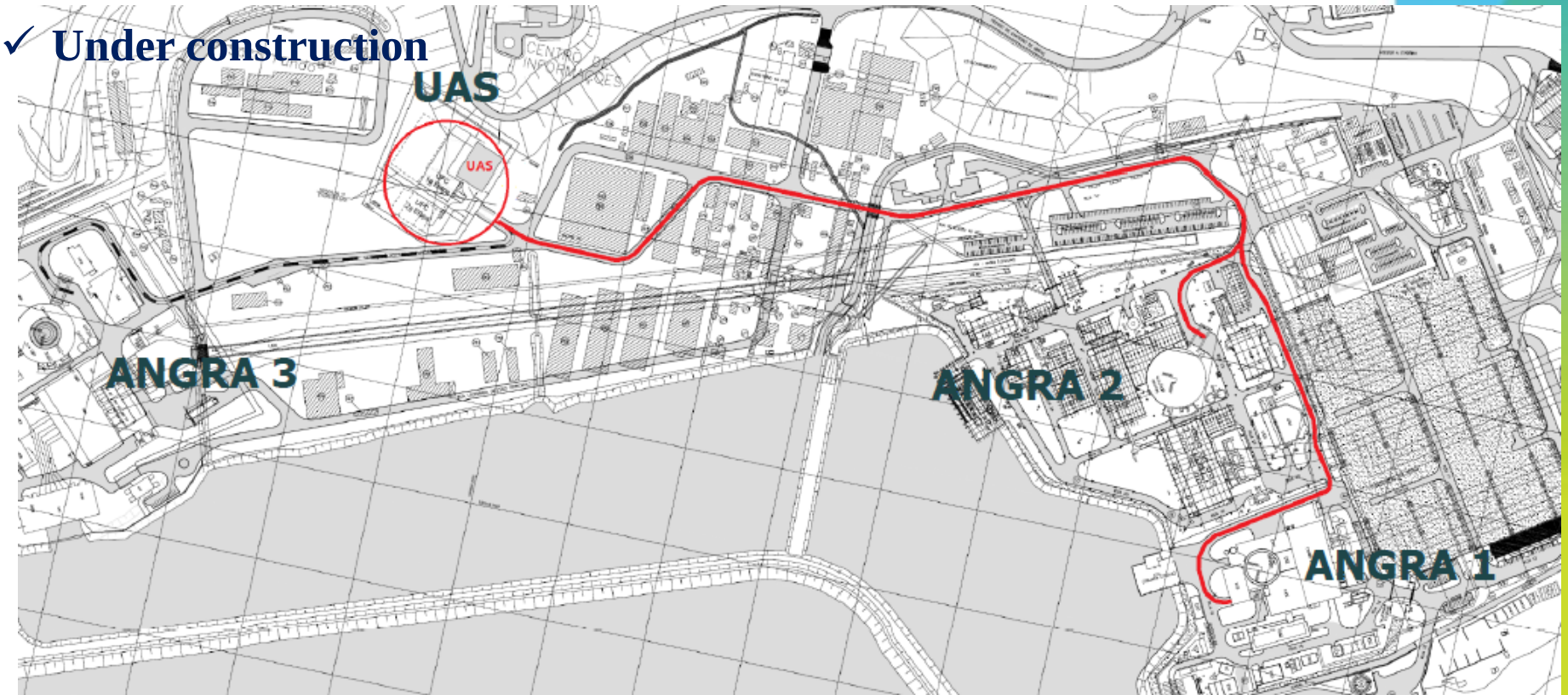
8. IX - Spent Fuel Management

NPP	Storage Capacity (cels)	Cels used	SFA inside the core	End of capacity forecast
Angra 1	1.252	978	121	Dez/21
Angra 2	1.084	756	193	Jul/21

JUNE 2018

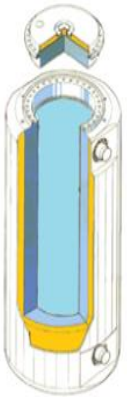
- ✓ **ISFSI to be constructed until 2020**
  UAS (Unidade de Armazenamento a Seco – Dry Storage Unit)

- ✓ **Under construction**

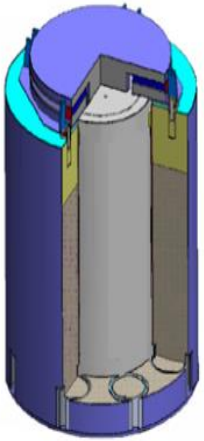


8. IX - Spent Fuel Management – Dry SF Storage

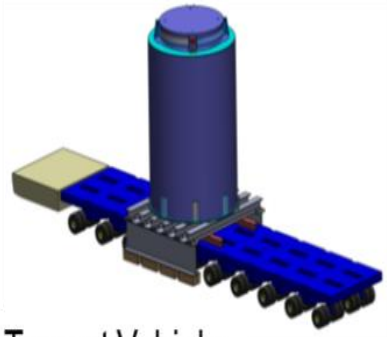
Canister



Transport cask



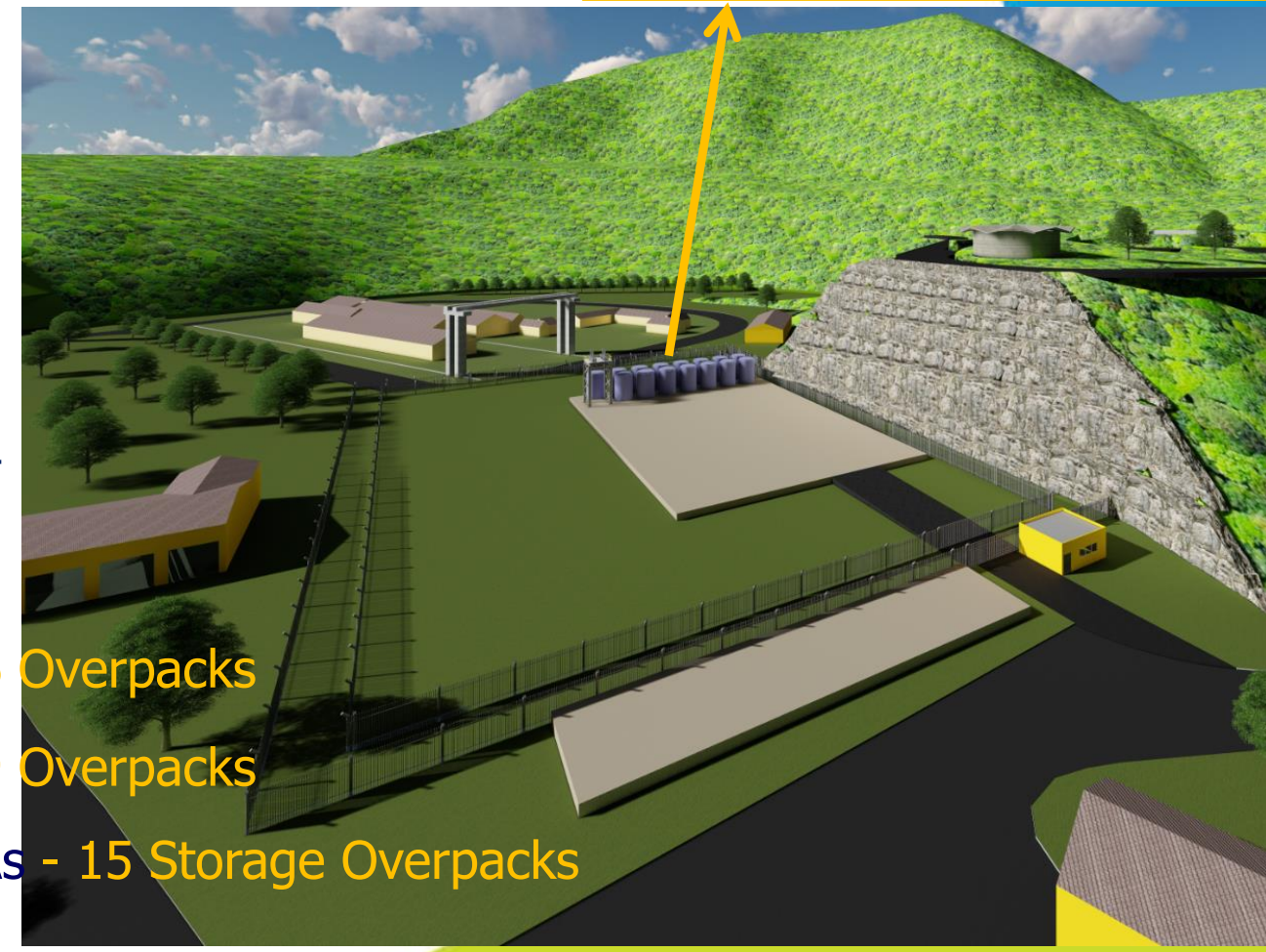
Overpack Storage



Traport Vehicle

8. IX - UAS – ISFSI – Dry SF Storage

- ✓ **VERTICAL**
- ✓ **Short Schedule**
- ✓ **Worldwide implemented**
- ✓ **Certified solution > NRC licencing**
- ✓ **Expandable – 15 >> 72**
- ✓ **HOLTEC INTERNATIONAL BID - Winner – Turn Key**



- Angra 1: 222 SFAs - 6 Overpacks
- Angra 2: 288 SFAs - 9 Overpacks

Total: 510 SFAs - 15 Storage Overpacks

8.X - Radiation and Hot Spots Removal / Reduction

- ✓ **~ chemical decontamination**, easy-to-remove **hot spots** should be removed **x** interface to **chemical decontamination**. Similarly, CD may relocate some hot spots.

- ✓ Hot spots removal proposed after the radiometric survey of the plant areas, >> Considered deferred dismantling.

- ✓ EPRI recommends that identification and removal of hot spots in two steps >> **before chemical decontamination and after** >> new points after this activity.

- ✓ As Angra 1 probably will do a chemical decontamination near its dismantling, it will only have hot spots identification / removal / analysis phase.

8.XI - Asbestos Insulation Removal

- ✓ Angra 1 NPP records showed that no Asbestos were used during its construction, so this item is not applicable

8.XII - Decommissioning and / or release of non-radioactive systems and buildings

- ✓ For Angra 1 NPP is proposed to not dismantle any non-radioactive building or systems until a **final company's decision** about what will be done after the installation:

- ✓ restricted or unrestricted use? will be reused for industrial purposes? will be dismantled and demolished?? if there is a possibility of construction of another reactor on site??.

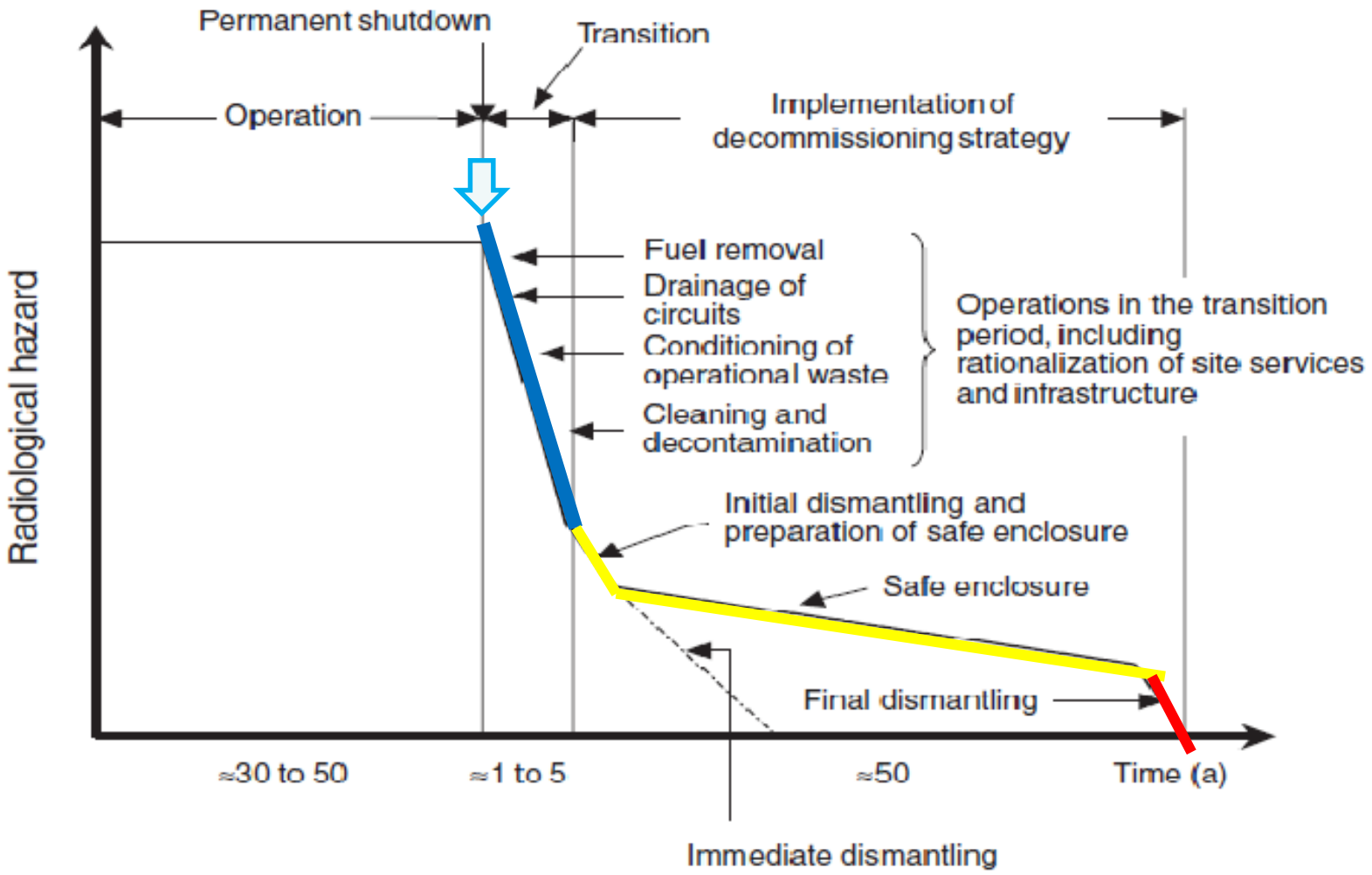
- ✓ **Non-radioactive buildings can also be used as support**, with the function of increasing the capacity to waste storage or decommissioning specific equipment,.

8.VIII - Changes for removal and/or maintenance of systems and technical specifications

- ✓ Many systems and equipment may be shut down and a request may be made to reduce or eliminate technical specifications accordingly

Some Systems to be maintained	Justification
Instrument Air System / Service Air System	Provide air supply for equipment and systems associated with SF handling.
Control Room Air Conditioning System	Provide habitability in the control room for monitoring and operation of the necessary systems.
Unrestricted Access Area Air Conditioning System and Technical Support Center	Provide access to the fuel building and technical support center
Communication system	Maintain communication between control room and SFP during activities.
Electrical Distribution of the Plant and to the external area	Maintenance of external power source for essential security and surveillance functions
Battery Room Exhaust System	Maintain battery operability to provide electrical power in case of external electrical distribution failure
Diesel Generators 1A / B, 3 and 4 Systems	Provide electricity in case of failure in the distribution of external electricity.
Nuclear Fuel System	Enable SFA handling during transfer activity
Meteorology System	Provide weather data to predict levels of radioactive release in case of accidents.
SF Pool Purification and Cleaning System / Refill Water Purification System	Maintain proper cooling and shielding water condition in the SFP.
Service Water System	SFP secondary cooling source
Fire Protection System	Due to the fire load remaining in the SFP building
Radiation Monitoring System	Due to permanence of combustible elements in SFP and radioactivity
Boron Recycling System	Maintenance of appropriate boron concentrations in SFP
Component Cooling System	Provide cooling to the SFP primary cooling system
Water Treatment System	Required for decontamination of equipment and accessories.

8.XIV - Safety Assessment

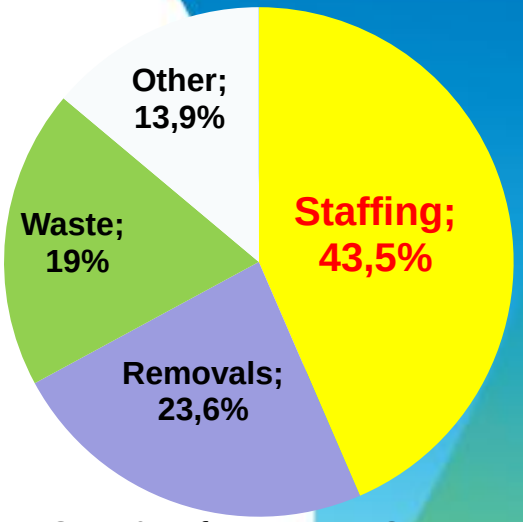


Transitional decommissioning operations and typical durations for the 'safe enclosure' option (IAEA, 2004)

8. XV - Cost Estimate for TPA1 – Order of Magnitude

Assumptions:

- **>> 43,5% of the Decomm. costs from Staffing ***
- Actual Staff of Angra 1 operation and maintenance, with 50% of decrease
- Medium Brazilian salary estimate + taxes and other tributes
- 3 to 5 years of Transition Period Duration



Cost % of Decomm Cost* - EPRI US exp

Transition Period Cost - Order of Magnitude (US$)			
Plant / Period	**3 years**	**4 years**	**5 years**
Angra 1	**108.784.788**	**145.046.384**	**181.307.980**
Angra 2	**110.380.960**	**147.174.613**	**183.968.267**
Angra 3 (~A2)	**110.380.960**	**147.174.613**	**183.968.267**

*Kim, K. & McGrath, R., Factors Impacting Decommissioning Costs,.WM2013 Conference, February 24 – 28, 2013, Phoenix, Arizona, USA. Disponível em < http://www.wmsym.org/archives/2013/papers/13576.pdf

8. XVI – Transition Period Activities Summary

1. PRE-PLANNING

1.1. Licensing planning

- Certificate of Permanent Termination of Operation and Removal of SFA
- Post shutdown decommissioning activities report (PSDAR)
- Review of the DCE and Transition Period Costs
- Irradiated Fuel Management Plan (IFMP)
- License Termination Plan (LTP)
- Post Defueled Technical Specifications Request (PDTS)
- Permanent Shutdown Emergency Plan (PSEP)
- Physical Protection Plan for Permanent Shutdown and Exception Requests
- Prepare a Quality Management Plan without SFAs
- Requalification Program for Operators / Fuel Handling Training and Certification Program (CFH)
- Request exclusions from the nuclear insurance policy
- Specific Safety Analysis for the Transition Activities
- FSAR review considering permanent shutdown

1.2. Review of programs and procedures
1.3. Review and Analysis of HSA / Updated Radiometric Survey
1.4. Hazardous material survey and analysis
1.5. Preparation of contract with support consulting company
1.6. Planning for Cool and Dim Condition
1.7. Communication Plan
1.8. Human Resources Plan with organizational restructuring of the company during the TPA1.

IAEA + EPRI

2. PERMANENT SHUTDOWN ACTIVITIES

2.1. Plant Shutdown and Inspection
2.2. Removal of SF and materials
2.3. Draining and drying all systems that are unnecessary
2.4. Sampling for characterization of radiological inventory
2.5. Removal of fluids from systems (water, oils, etc.)
2.6. Chemical decontamination of systems for dose reduction (if applicable)
2.7. Removal of decontamination waste
2.8. Removal of combustible material
2.9. Removal of used resin
2.10. Removal of other radioactive waste from operations
2.11. Electrical isolation of equipment
2.12. Asset recovery: resale / transfer of plant equipment and components such as surplus stock to other licensed facilities (contaminated material) and unlicensed (uncontaminated material)

8. XVI – Transition Period Activities Summary

3. EQUIPMENT CONTRACTS AND GENERAL MATERIALS

3.1. General equipment for dismantling
3.2. General equipment for decontamination of personnel and tools
3.3. General equipment for radiological protection
3.4. General Physical Security Equipment and Maintenance for Long Term Storage Safe Storage
3.5. Acquisition of casks for SFAs
3.6. Acquisition of transfer casks for LLW / ILW / HLW to the final repository (to be built)

IAEA + EPRI

4. SAFE STORAGE PREPARATION ACTIVITIES

4.1. Decontamination of areas and equipment to facilitate dismantling (if decided for specific cases)
4.2. Drainage of the SFP and decontamination (if applicable)
4.3. Dismantling and transfer of contaminated equipment and material for long-term storage / Final repository of radioactive waste
4.4. Sampling for the characterization of the radiological inventory in the facilities for the safestorage
4.5. Site reconfiguration, isolation and protective structures
4.6. Characterization of the radiological inventory for decommissioning and decontamination
4.7. Preparation of the temporary RW storage area (if necessary)
4.8. Removal of fuel handling equipment (if necessary)
4.9. Personal training
4.10. Asset recovery: Sale / transfer of the metal or materials and equipment saved or components for recycling or reuse (partial)
4.11. Cool and Dim Condition Implantation
4.12. Evaluation and removal of hotspots (where applicable)
4.13 SITE PHYSICAL SAFETY PLANNING, MONITORING AND MAINTENANCE DURING SAFE STORAGE
- 4.13.1. Operation of physical security and site surveillance
- 4.13.2. Inspection and maintenance of buildings and systems in operation
- 4.13.3. Site conservation
- 4.13.4. Energy and water supply
- 4.13.5. Radiological and environmental periodic survey

8. XVI – Transition Period Activities Summary

5. PROCESSING RADIACTIVE WASTE, STORAGE AND DISPOSAL

5.1. Radioactive Waste processing, storage and safety analysis for disposal
5.2. Feasibility studies on waste transport
5.3. Special permissions, packaging and transportation
5.4. System fluids (water, oils, etc.) processing
5.5. Decontamination waste processing
5.6. Operation Fuel Material processing
5.7. Spent Resins processing
5.8. Other nuclear and hazardous materials from facility operations
5.9. Storage of waste from operation
5.10. Disposal

IAEA +

EPRI

6. PROJECT MANAGEMENT, ENGINEERING AND SUPPORT

6.1. Mobilization and preparatory work
6.2. Project and engineering management services
6.3. Public relations
6.4. Support Services
6.5. Radiotiological Protection
6.6. Restructuring Human Resources

7. RESEARCH AND DEVELOPMENT

7.1. Research and development of the decontamination process, measurement of radioactivity and dismantling processes, tools and not usual equipment
7.2. Simulation and modeling of more complicated tasks
7.3. Search for international experiences and updated lessons learned

8. SPENT NUNCLEAR FUEL MANAGEMENT

8.1. SNF transportation to UAS
8.2. Transportation for final Disposal (when ready)

8. XVII – Conclusion and Remarks

- ✓ The TP of a NPP, **begins with planning for the reactor shutdown >> Decommissioning or Safe Storage**
- ✓ **TP ssential phase in the life cycle** of a nuclear facility and must be **periodically updated** as well as the Preliminary Decommissioning Plan, which in Brazil is required every 5 years according .
- ✓ **Important** to be **prepared** for **unplanned conditions**
- ✓ **Great complexity and multidisciplinary project** >> will be required great effort from all areas of the company to complete it safely and within the cost and time planned
- ✓ **Regulations in Brazil does not yet clearly contemplate** this period and are still under development >> NRC licencing >> well-structured and detailed licensing process
- ✓ **Well-defined and clear communication plan** for the stakeholders is of great importance

8. XVII – Conclusion and Remarks

- ✓ The **organizational structure will need to be reformulated before, during and after** TPA1. **Strong Human Resources needed**.
- ✓ **Systems and Technical Specifications to be carefully evaluated**
- ✓ **Decommissioning strategy** for CNAAA and Angra 1 **directly influences TP planning**
- ✓ **Project Management Methodology** needed and a previous fucused staff for planning 5 years before Permanent shutdown
- ✓ **Cost of the TP have to be considered and collected previusly** inside the Decommissioning Trust Fund
- ✓ **National RW Repository is needed for LLW, ILW and HLW**

"The pessimist sees difficulty in every opportunity.

The optimist sees the opportunity in every difficulty."

Winston Churchill

Thank you!

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