

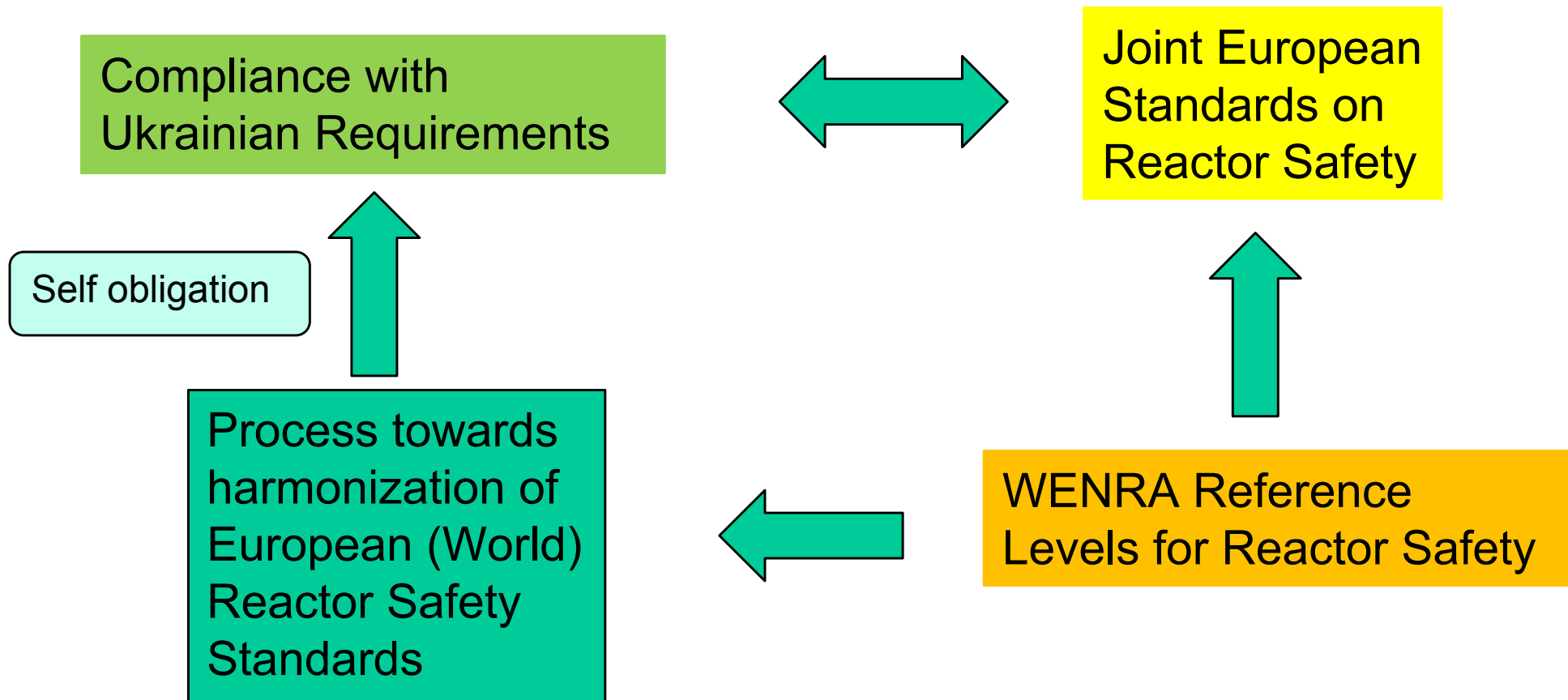
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Improving the safety of Ukrainian NPP to reach an internationally accepted level

Basis of assessment of Ukrainian NPPs

Internationally accepted level of safety?



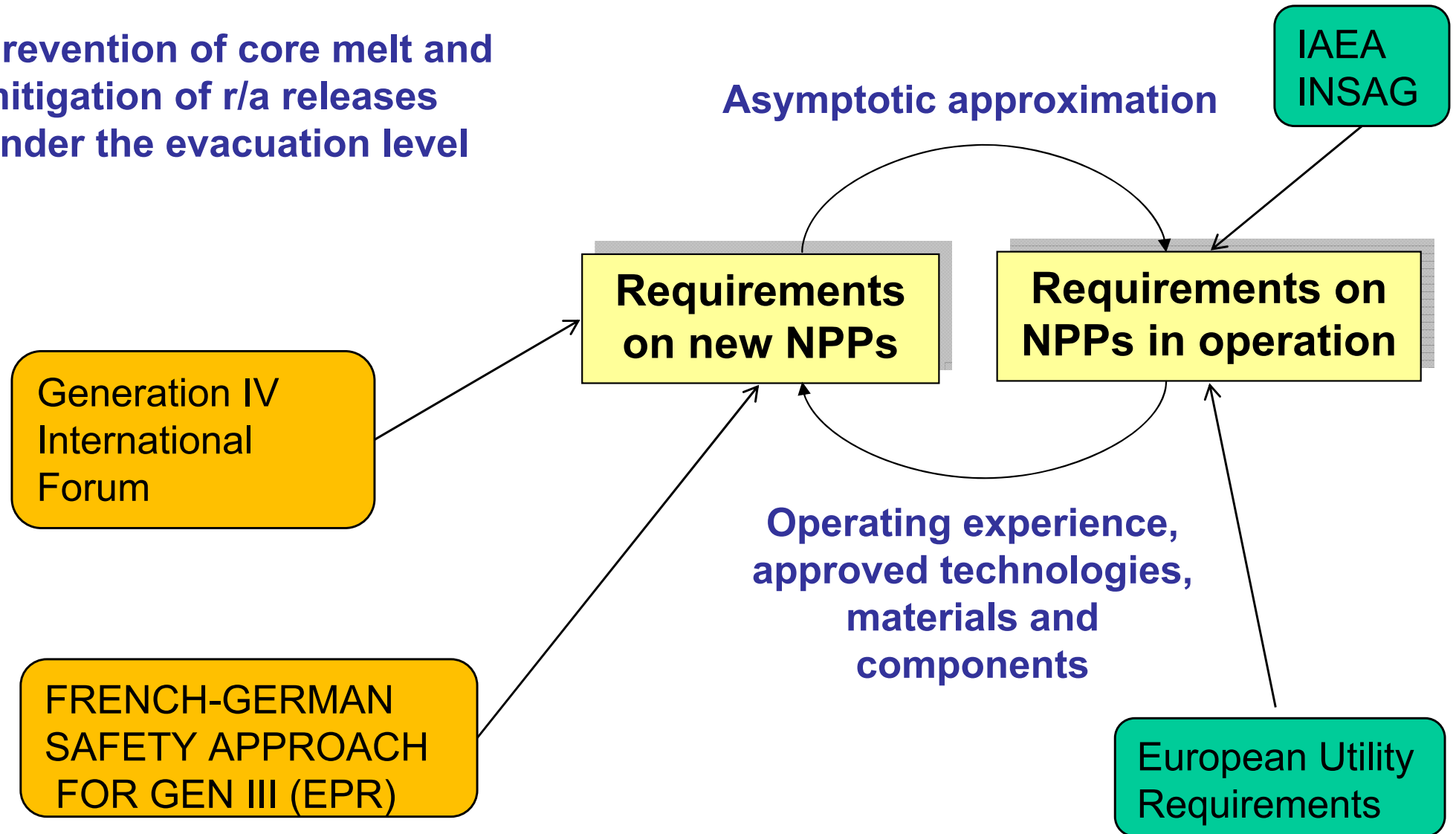
Let's have a look on the Ukrainian pool of NPPs, before showing how the bottleneck - **Internationally accepted level of safety** - was solved.

15 NPPs nominal power = 13.835 MW (~ 27%)
Share of nuclear energy production 47,4 % in 2007 (→52%)



Two NPP generations - GEN-2 and GEN-3 - will be operated at the same time with different safety levels.

Prevention of core melt and mitigation of r/a releases under the evacuation level



Main differences between GEN-II and GEN-III

- Scope of design basis accidents,
- Capacities to withstand external hazards,
- Degree of human failure forgiveness,
- Probabilistic criteria with consequences on the emergency planning

Ukrainian Probabilistic criteria	Obligatory value/year	Target value/year
Core damage frequency	$<10^{-5}$	$<5*10^{-6}$
Large release frequency	$<10^{-6}$	$<10^{-7}$

Two WWER generations - GEN-2 and GEN-3 - will be operated at the same time with different safety levels

- Ukrainian WWER → three types of the GEN-2 design
- End of Plant Life Time 2010 – 2019, except Z6 (2025), K2/R4 (2034)
- WWER-1000 Tianwan/China of preliminary GEN-3 design
- Completion of interrupted construction in Bulgaria and Ukraine
 - Belene – to remove the existing construction and build a new GEN-3 AES 2006/WWER-1200
 - Khmelnytsky-3,4 – not decided yet

NPP Khmelnytsky with 4 WWER-1000 – 2 in operation and 2 with interrupted construction (completion decided Oct 08)



Agreement on internationally accepted level of safety

Even if the international accepted safety level for operating NPPs is not strictly defined in an international regulatory document it is accepted to compare the current status of WWER countries and reactors with

- WENRA Reference levels (harmonization of regulations)
- Level of the “elimination” of the “Safety Issues” identified in the **IAEA “green” books** for each of the WWER type reactor.

Investigation of the gaps between international accepted level and the status of Ukrainian NPPs

1. Along with the IAEA “green books” often supported by TACIS
 - Specific investigations and hardware implementation with international support.
2. TACIS review of the modernization programs
 - K2/R4 (internationally agreed)
 - Remaining 13 NPPs (Safety improvement concept)
3. EC-IAEA-UKRAINE JOINT PROJECT on Safety Evaluation of Ukrainian NPPs - MoU on co-operation in the field of energy between the EU and Ukraine (2008-2010)
 - Design (NS-R-01) and operational safety (OSART), Waste management and decommissioning, Regulatory issues (IRRT)

Well known safety status of Ukrainian NPPs

- 15 years - international assistance in bringing the Ukrainian nuclear area into compliance with internationally recognized practices by TACIS, IAEA (OSART, IRRT, MoU) and bilateral programs.



See the following slide

Qualified operation and licensing and supervision procedure ↔ Internationally supported & monitored

- Utility's responsibility on nuclear and radiation safety
 - ➡ WANO, Twinning, IAEA, USDOE and bilateral programs
 - "green" books as a basis for modernization programs.
 - Safety management with strong preventive attitudes (ALARA), equipment and personal qualification, safety demonstration
- Regulator's duties
 - (1) Licensing (6 licenses for four sites and R4/K2 separately)
 - (2) Safety review ← SAR, Code transfer, PSA, US-German-Ukrainian Peer Reviews of PSA.
 - (3) Rulemaking, e.g. OPB, PBYa ← INSAG, WENRA
 - (4) Supervision ← inspection by TACIS, IAEA, Cooperation Forum


Modernization of Ukrainian NPPs

- NPPs except K2/R4: 386 measures within 2006-2010
 - Credit agreements with EBRD/EURATOM from 2004
 - July 2008: 138 measures completed.
 - K2/R4: 147 measures before and after start-up 2004 → 2009.
 - Partly financed by EBRD/EURATOM loans.
 - Internationally reviewed and inspected.
 - October 2008 remaining measures: K2 → 16, R4 → 6.
- ➡ to bring the plants in compliance with the international accepted level of NPP safety.

Objectives of the Safety improvement concept 2006-10

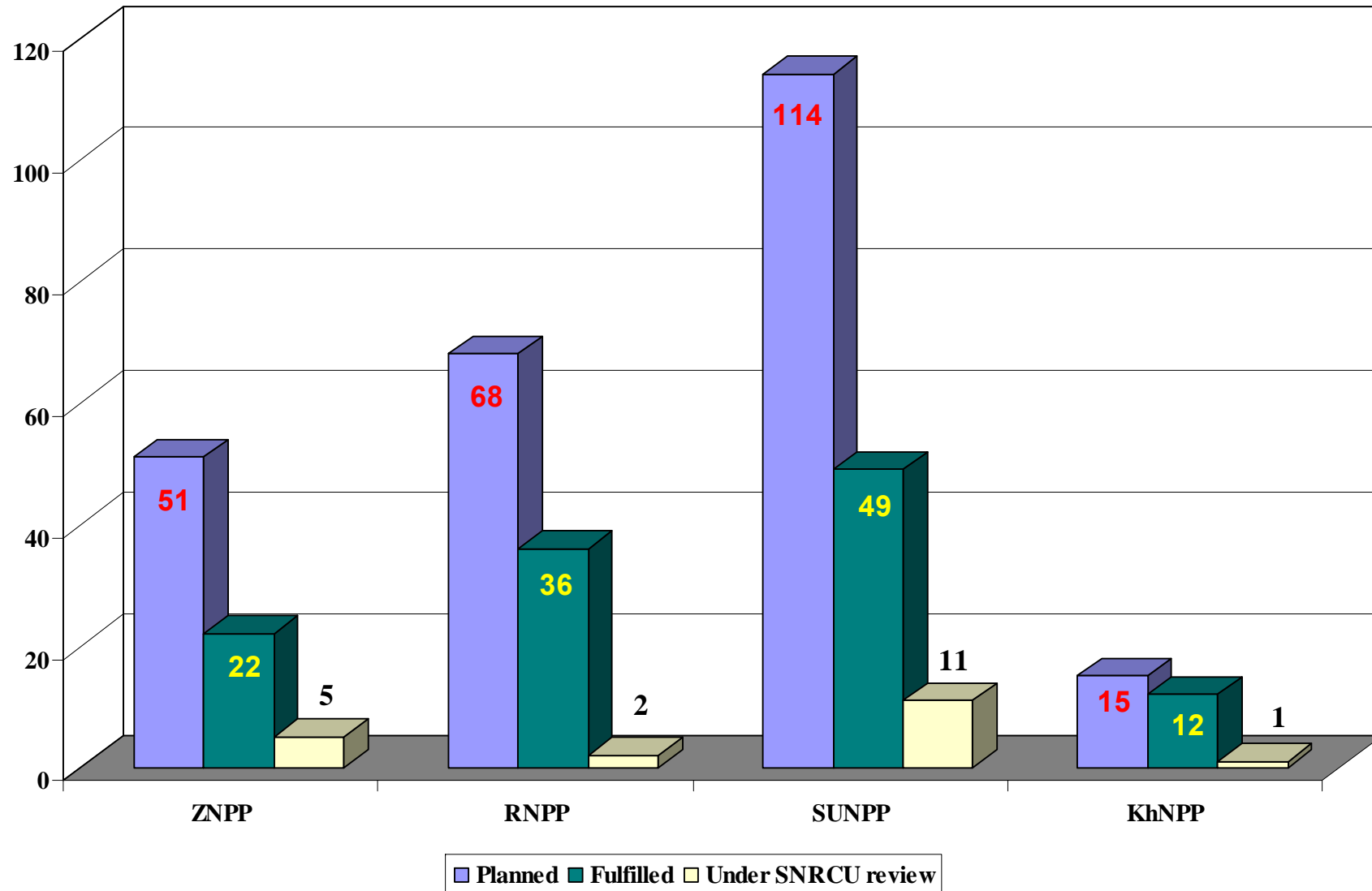
- Bringing into accordance with the national safety requirements.
- Resolving the issues of the IAEA “green books”.
- Maintaining the general safety concept and the design basis.
- Identifying further risk reducing areas of improvement (PSA).

Remarks:

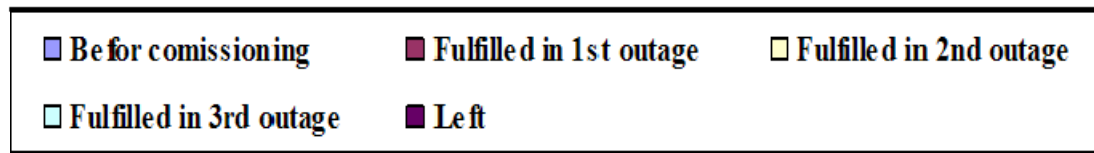
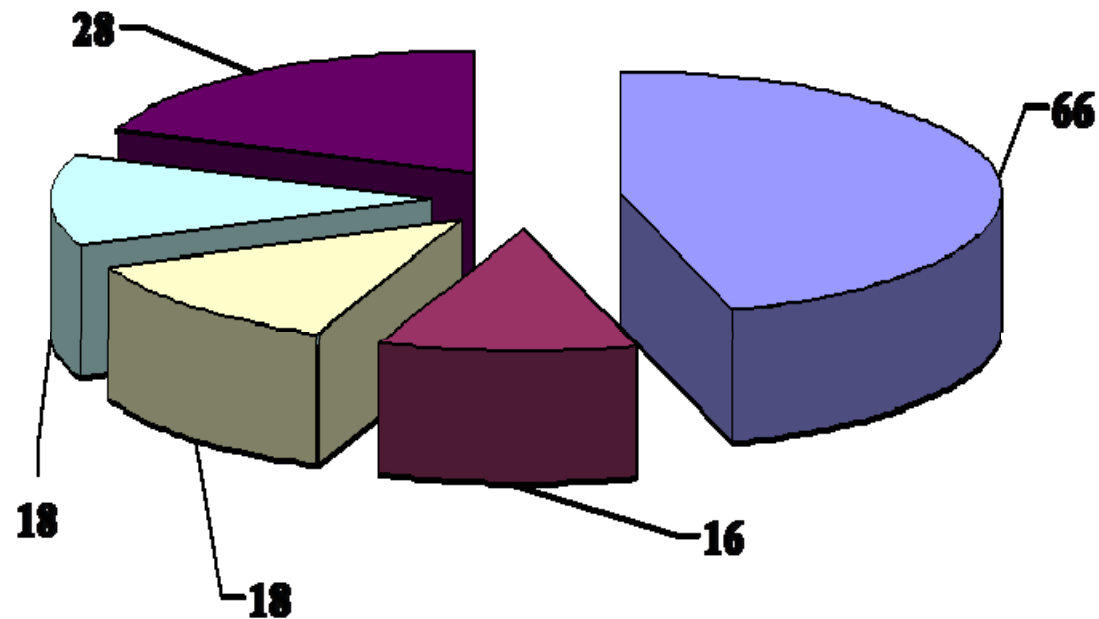
- PSA competence is available
- The verified quality of PSA for the three pilot units is more urgent than a line production of PSAs with indefinite actuality. Analysis should provide an added value, too.
- Maintenance of standardization of design & modernization  experience feedback, unified procedures, assessment tools.

Safety improvement concept 2006-2010

Status on 04/07/2008



Fulfillment of safety improvement measures at K2 Status on October 2008



Examples of defense in depth improvements Level 1

Equipment qualification (harsh and seismic conditions) Plant life time management program	<ul style="list-style-type: none">• Ongoing by testing, analysis,• EQ transfer from other NPPs and• re-placement (BRU-A)
Inherently stable reactor behavior, e.g. negative moderator feedback	<ul style="list-style-type: none">• Fuel loading.• Interlock preventing the parallel increase of reactivity by boron and control rods.
Improvement of reliability ↑	<ul style="list-style-type: none">• Resistance to dependent failures of steam&feed water piping (LBB, super pipe concept and/or reconstruction)• qualified safety and relief valves (base safety + feed&bleed)
Avoidance of copper and salt intrusion into the Steamgenerators as a result of turbine condenser leaks	<ul style="list-style-type: none">• Replacement of copper to stainless steel (pre-heaters and turbine condensers).• Condenser leak protection and purification.

Examples of defense in depth improvements Level 2

Man-machine interface	Reconstruction of control rooms. Periodic full scope simulator training. SPDS (safety parameter display) . PAMS (post accident management system). TV-monitoring. Diagnostic systems.
Reliable limitation systems	Fast cooling down by 60°C/h. In-core controlled power distribution Primary-secondary leak detection with N¹⁶

Examples of defense in depth improvements Level 3

<p>Design criteria with margins</p>	<p>Optimized ECCS with overlapped pressure diapasons</p> <p>Back-up of HP ECCS by make-up system</p> <p>Prevention of thermo shock by increased temperature of ECCS storage water, fast cool down, control of HP ECCS injection.</p>
<p>High reliability of safety systems by redundancy, physical separation and diversity</p>	<p>Two complete sets of Reactor Control & Protection</p> <p>New scram criteria: $p_{SG} > 80 \text{ bar}$ $dT_{\text{saturated}} < 10^\circ\text{C}$</p>
<p>Single failure criterion in all states including shutdown</p>	<p>Redundancy of impulse lines for safety relevant measurements</p>
<p>EOP</p>	<p>Symptom oriented EOP</p> <p>Controlling the PRISE LOCA based on reliable leak diagnostics and prevention of r/a water release into environment.</p>

Examples of defense in depth improvements Level 4

<p>↓ CCF (multiple failures, e.g. loss of HP ECCS pumps, blocking of core cooling channels)</p>	<p>New thermo insulation and sump designs with increased filters</p>
<p>Reliable primary and secondary feed&bleed</p>	<ul style="list-style-type: none"> • Three redundant safety valves (2009) • additionally secondary feed&bleed by use of <ul style="list-style-type: none"> • new safety valves (bleed) and for feed • EFW or fire protection system.
<p>High degree of diversity of safety support systems Diverse power supplies for station black out</p>	<p>add. DG and independent off-site power sources, e.g. Tashlyzkaya hydro power station Increased capacity of accumulator batteries + reloading since the beginning of accident</p>

Replacement of thermo-insulation



Examples of defense in depth improvements Level 5

Planning of measures on personnel and public protection.

- Internal and external crisis centers
- State of the art radiation supervision by ASKRO
- Emergency exercises

Comments on modernization programs

- Eight modernization programs since the Nineties, allocated to different documents with indefinite completion status.
- The numerous programs were compiled into one document 2007 including the basis of EBRD/EURATOM Credits (update by MoU).
- The implementation schedules of improvement programs are generally too uneven so that many topics are scheduled to the end of each period making works sometimes under pressure.

Modernization → further challenges

- EQ
 - Seismicity
 - Plant life time management
- Accident management
 - SAMG and selected measures
 - Considering WWER features and capacities, e.g. large water inventories providing larger time windows.
 - BRU-A (water collection should be arranged somehow because main part of activity there)
- Waste management (including spent fuel storage)

Results

- NPP's safety has been improved through multinational financial support and technical expertise including grant delivery of components and systems, e.g.:
 - equipment for crisis centre, full scale simulators, safety valves, in-service inspection manipulators, diagnosis systems, fire protection equipment, generator...
 - Methodologies and tools for operator & regulatory training, deterministic & probabilistic safety assessments including SAR, rulemaking.
- **International accepted level** of safety will be reached
 - Rovno-4 and Khmelnytsky-2 in 2009
 - remaining 13 NPPs until 2010 (under TACIS review)

Results

- The safety improvements have mainly concentrated into technical improvements.
- However the **safety is at least** as strongly dependent on **human performance** as **material condition** and in the future safety management including e.g. training, use of procedures and attitude could be focused more.

Challenges for Ukraine

- PLEX is challenging the SUNPP-1,2 and RNPP-1,2 (2010)
- Maintaining the standardized design. Ukraine is in a good situation having only WWER reactors, but with different ageing and modernization status.
- A qualified assessment requires an independent review.
- **Don't lose track** – the highest priority have the monitored **level 1 base safety** and qualified **safety management**.

Challenges for the international community

- Updating the 15 years old IAEA “green” Issue Books?
- The better way would be to assess all European reactors including WWERs on a similar basis based upon
 - European requirements (WENRA, European Utility requirements, GEN IV International Forum ...) and
 - include also cooperation with Nuclear Power operators of EU
 - Not all upgrading made at WWER are fully implemented in older western NPPs, e.g. replacement of thermo insulation.
- The experience with the "Roadmap on nuclear safety“ in Ukraine should help, hopefully in the near future, to agree on
➡ Joint European standards on Reactor Safety.

Zaporizhzhya NPP with 6 WWER-1000 biggest NPP in Europe

