Management of Spent Nuclear Fuel and High-Level Waste as an Integrated Programme in Switzerland

Nuclear Waste Technical Review Board
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NPP Goesgen (KKG) Presentation to NWTRB

1. Introduction
2. KKG's back-end strategy and related transport issues
3. Legal and technical constraints
4. Transport planning
5. Lessons learned

KKG Bildarchiv

Kernkraftwerk Gösgen-Däniken (KKG) Technical Data

- Siemens design 3 loop PWR
  - Located in northern Switzerland
  - In commercial operation since 1979
- Output 3,002 MW(thermal) /1,060 MWe gross/1,010 MWe net
  - Availability 93% in 2017
  - 2017 net electricity production 8.154 TWh (billion kWh)
- Operating cost around 2.4 US cents/kWh
  - Including provisions for back end fuel cycle costs

KKG Shareholders

- Alpiq AG, Olten 40%
- Axpo Power AG, Baden 25%
- Centralschweizerische Kraftwerke AG (CKW), Luzern 12,5%
- Energie Wasser Bern (ewb), Bern 7,5%
- Stadt Zürich 15%

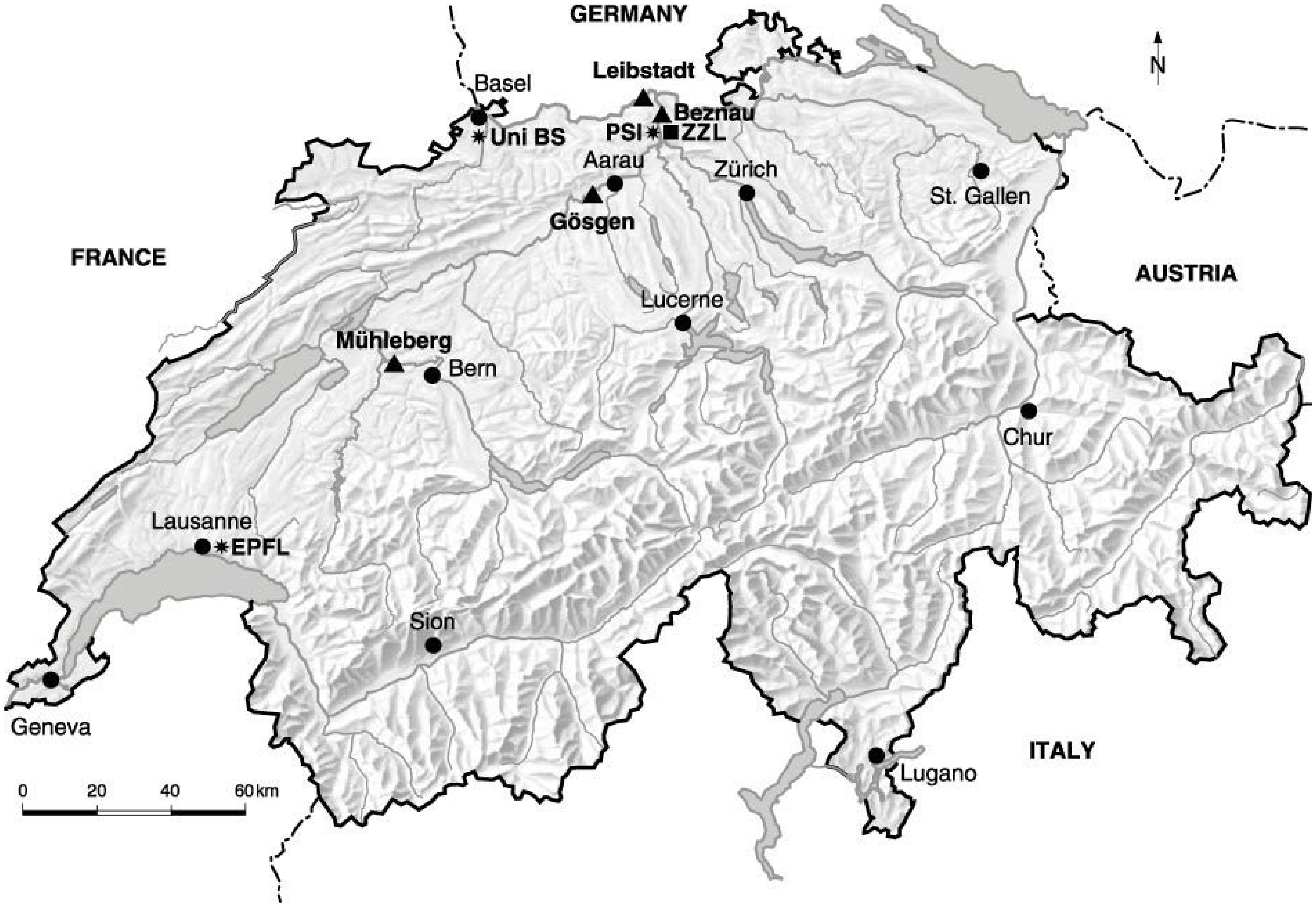
KKG Current Operation

- 5 region core operation
  - Core has 177 Fuel Assemblies (FA)
  - Annual reload 36 FA with 4.95% enriched uranium equivalent
  - FANP 15x15-20 design fuel with Duplex cladding (outer liner)
- Current core comprises mostly reprocessed uranium
  - Average discharge burn-up of uranium fuel ≈ 65 MWd/kgU
  - In the past a total of 160 mixed oxide (MOX) FA were also loaded
  - Future reloads based on enriched natural uranium oxide (UOX)
- Expected Operating Lifetime 60+ years
  - Subject to periodic safety assessments every 10 years
  - Currently planning is to operate to 2039
  - Further life extension is feasible, so long as reactor can operate safely and is environmentally and economically viable

Nuclear Power in Switzerland

- Total Swiss Electricity Production 58.5 TWh (billion kWh) in 2017
  - Nuclear generation 19.5 TWh
  - Five nuclear power plants – 2 BWR, 3 PWR (3,388 MWe)
- National Energy Strategy 2050
  - Intention to reduce energy demand and increase use of renewable energy
  - No new nuclear power plants to be built
  - No artificial restriction on operational life of existing plant
- Back-end policy
  - No more reprocessing (new commitments effectively banned since 2006)
  - Interim storage of spent fuel at power plants and in central facility (Zwilag)
  - Long term storage in deep geological repository
  - Site selection underway – repository is planned to operate 2060 - 2075

Location of Swiss nuclear sites, including Zwilag (ZZL)



KKG’s back-end strategy and related transport issues

1. Reprocessing

- Contracts with France and the United Kingdom for reprocessing spent fuel:
  - 695 FA and one quiver sent to La Hague (F) using the TN12 transport cask
  - 273 FA sent to Sellafield (UK) using the NTL11 transport cask
  - Last transport of spent fuel made in 2006, when moratorium came into effect
  - All reprocessing is now finished
- High level waste (HLW) and intermediate level waste (ILW) from reprocessing this fuel returned to Switzerland over period 2001 to 2016:
  - 196 vitrified HLW canisters (CSD-V) from La Hague using six TN81 and one CASTOR CG 20/28 transport and storage casks
  - 228 compacted ILW canisters (CSD-C) and 1 vitrified ILW canister (CSD-B) from La Hague using the TN81 as a transport only shuttle cask (20 per cask)
  - 84 vitrified HLW canisters from Sellafield using the TN81 transport and storage cask (3 casks)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KKG’s back-end strategy and related transport issues

2. Demonstrating feasibility of dry storage in Zwilag

- Zwilag – centralised interim storage of spent fuel and nuclear waste
  - Spent fuel and HLW stored in dry casks
  - ILW and LLW (low level waste) in vault storage
  - Owned jointly by the Swiss NPPs (KKG share 31.2%)
  - Constructed 1996 -2000 - operating since 2001
- Transport and storage of spent fuel and HLW
  - Transports of spent fuel from KKG took place in 2002 - 2003, utilising the TN24 G (4 casks each with 37 fuel assemblies)
  - Transports of KKG HLW from La Hague took place in 2001 - 2016 (7 casks)
  - Transports of KKG HLW from Sellafield took place in 2015 (3 casks)

Zwilag – centralized interim storage facility


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KKG’s back-end strategy and related transport issues

3. External wet storage facility

- KKG was built with the expectation that fuel would be reprocessed
  - Reactor pool has 656 fuel positions in total (inside the containment)
  - 177 positions required for Full Core Reserve
  - Some positions unavailable, blocked or otherwise utilised
  - Total of 439 available positions
- Need for additional capacity identified due to reprocessing moratorium
- Wet vs Dry storage? Key issues for KKG in favour of wet storage
  - No suitable cask design available for dry storage of all KKG fuel
  - Wet storage offers more flexibility
  - Additional cooling time allows for optimised cask loading later
  - Possible use of wet store for longer term interim storage

KKG's back-end strategy and related transport issues

3. External wet storage facility (cont.)

- Construction
  - External pool constructed on the KKG site
  - Applied for permit 2002
  - Commenced construction 2004
  - Entered service 2008
  - Currently 504 positions – potential to increase to over 1,000 positions
- Operation
  - Spent fuel transfers using TN12/2 B as shuttle cask
  - 12 UOX or 4 MOX and 8 UOX fuel assemblies per transfer
  - 3 to 4 shuttle campaigns every year

KKG's back-end strategy and related transport issues

4. Development of new cask design

- On site storage sufficient to at least 2027
  - Additional capacity required to EOL (2039 or later)
  - Aim to remove all fuel from site ASAP after shutdown
- KKG cannot buy an "off-the-shelf" cask due to very exacting technical requirements
  - UOX fuel 4.95% U235 equivalent: burn-up up to ca. 70,000 MWd/itHM
  - MOX fuel burn-up up to ca. 60,000 MWd/itHM
  - New design to be developed for KKG fuel to meet 2027 deadline
- 15 year lead-time required
  - Initial feasibility studies 2013
  - Request for proposals issued 2015
  - Supplier selected and contract signed end 2016

KKG's back-end strategy and related transport issues

4. Development of new cask design (cont.)

- Use of extended on-site storage to maximise fuel cooling and optimise cask utilisation
  - KKG has allocation of 77 cask positions in Zwilag
  - 14 of these are in use: 63 are still available
  - A cask with a capacity of 32 FA would allow for 70 years' operation

KKG's back-end strategy and related transport issues

5. Post Irradiation Examination (PIE) of spent fuel

- KKG has an extensive fuel development program, including PIE
  - PIE conducted off-site at the Paul Scherrer Institute in Switzerland (PSI) and the Institute for Transuranium Elements (ITU) in Germany
  - Irradiated fuel rods are transported to PSI/ITU
  - After examination the material is encapsulated and returned to KKG
  - Transports currently made using the R-72 and NCS-45 casks
- Concept for long term storage / disposal of encapsulated rods being developed
  - Similar concept required for damaged fuel rods
  - Reprocessing is no longer feasible
  - Storage / disposal in quivers is a possible option
  - Other options also under active consideration

Legal and Technical Constraints

- Statutory basis of Nuclear Power
  - Initial basis was the Atomic Energy Act 1959
  - Replaced by the Nuclear Energy Act 2003, RS 731.1
- Establishment of independent regulatory authority (ENSI)
  - Swiss Federal Nuclear Safety Inspectorate Act 2007, RS 732.2
- Environmental Protection
  - Federal Act of 1983 on the Protection of the Environment, RS 814.01
  - Federal Act of 1991 on the Protection of Waters, RS 814.20
  - Radiological Protection Act of 22 March 1991, RS 814.50
- Related ordinances (regulations)
  - At least 15 relevant regulations
- ENSI guidelines
  - Over 40 guidelines currently in force, plus additional recommendations

International Obligations

- Nuclear Safeguards
  - International Atomic Energy Agency (IAEA) 1957
  - Nuclear non-proliferation treaty 1978
  - Bilateral agreements with USA, Australia, Canada, Russia etc.
- International Conventions, including:
  - Nuclear Safety
  - Safety of spent fuel management and radioactive waste management
- Transport specific standards
  - IAEA Safety Standards, Regulations for the Safe Transport of Radioactive Material, No. SSR-6 (2012)
  - European Agreement on the International Carriage of Dangerous Goods by Road (ADR) and by Rail (RID)
  - International Maritime Organization (IMO) Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes in Flasks on Board Ships

Changes to licensing procedure

- Until now casks have been licensed for transport in their country of origin
  - The transport package approval has then been validated by the Swiss regulator (ENSI) based on the Safety Analysis Report (SAR)
  - Storage approval has been given directly by ENSI based on the Topical Safety Analysis Report (TSAR)
- For new cask design KKG will submit an Integrated Safety Case for ENSI approval covering both transport and storage
  - This means ENSI will approve both transport and storage aspects
  - ENSI however can also license packages based on SAR and TSAR

Transport Requirements

- Basic principles based on compliance with SSR-6, ARD, RID etc.
  - Prior to SSR-6, TS-R-1 was applied
  - wherever applicable international conventions have been incorporated into Swiss law
  - Transports of spent fuel and high level waste require Type B package approvals
  - Defined standards for shielding, containment, heat transfer, confinement and maintenance of sub-criticality.

Storage Requirements

- The key guideline to follow is ENSI-G05
  - This is applicable to the design, manufacturing and use of transport and storage casks, which are used for dry storage of spent fuel assemblies and of vitrified high-level waste in interim storage facilities
  - This guideline defines the safety related requirements applicable to the casks
  - Each cask is inspected during manufacture to ensure compliance
  - The specific design principles for interim storage facilities are specified in regulatory guideline ENSI-G04
- Key Requirements:
  - Demonstrate that the casks will withstand all static and dynamic loads during normal operation and under hypothetical accident conditions
  - Double lid system is mandatory for casks loaded with spent fuel assemblies

Storage Requirements

- Key Requirements (cont.)
  - Leak tightness for the entire planned period of interim storage under normal operating conditions
  - Sub-criticality of the stored fuel assuming the most unfavorable cask arrangement and complete flooding
  - Demonstrate adequate performance (resistance to ageing effects) during the planned usage period for all materials
  - Welds of pressure-bearing barriers to be designed as fully penetrating welding joints and shaped to allow ultrasonic testing
  - After an airplane crash followed by a kerosene fire the radiation dose received by individual members of the public must not exceed 100 mSv
  - Cask does not tip over during a Safe Shutdown Earthquake (SSE) and the adequate distance maintained between adjacent casks after an SSE
  - Dose rate and temperature limitations are defined

Aging Management

- Long term storage in Zwilag
  - Cask inter lid pressures are monitored continually while in storage
  - In the event of a problem, there is a hot cell facility in Zwilag where seals can be exchanged
  - If needed the spent fuel can be transferred into another cask in the hot cell
- Casks will need to remain fully functional until geological disposal
  - Fuel will then be repackaged in disposal canisters
  - For some casks this could mean over 70 years storage
    - Based on current planning assumptions of disposal by 2060 - 2075
  - Revised guidelines for aging management currently under development
  - Close collaboration with Zwilag and other utilities to resolve generic issues

Transport Planning

- KKG's approach to planning
  - Be conservative in your assumptions
  - Allow plenty of margin
  - Always have a "Plan B"
  - Identify the major stakeholders and keep them closely informed
  - Look for synergies to optimize processes and reduce costs
- All transports are governed by KKG's quality procedures
  - Clearly defined Quality Plans
  - Safety first!
  - Pre job and post job briefings
  - "Lessons Learned" utilized for the next transport

Outline schedule for an HLW transport

This schedule is based on KKG experience, using an existing cask design which needed to be relicensed to cover the inventory of nuclear material

- Year 1 — Initiate feasibility studies for cask design / interface
- Year 2 — Initiate investments on cask handling infrastructure
- Year 3 — Select supplier, negotiate contract, obtain board approval
- Year 4 — Start design and licensing work, commence forgings
- Year 5 — Submission of SAR to regulator in country of origin
- Year 6 — Submission of SAR & TSAR to Swiss authority (ENSI)
- Year 7 — Negotiate transport agreement. Delivery of accessories.
- Year 8 — Delivery of first cask to reprocessor ready for loading
- Year 9 — Approval for first cask loading
- Year 10 — Loading of casks 2 & 3 – transport to Zwilag, Switzerland

Outline schedule for a spent fuel transport

This schedule assumes a new cask design, which will have to be designed, licensed and may require tests to meet IEAE SSR-6 requirements

▪ Year 1	Feasibility studies for cask design / interface
▪ Year 3	Issue Request for Proposals (RFP)
▪ Year 4	Select supplier, negotiate contract, obtain board approval
▪ Year 5	Start design and licensing work
▪ Year 7/8	Submission of ISC to Swiss authority (ENSI)
▪ Year 11	Licensing completed, commence fabrication of first cask
▪ Year 15	Delivery of first cask to KKG ready for loading
	Approval for first cask loading
	Transport to Zwilag, Switzerland

Potential Risks

- Project Delays – main areas of risk
  - Design & licensing
  - Deviations during manufacture
  - Approval of manufacturing documentation
- Transport planning – main areas of risk
  - Safety and security is paramount
  - Need to avoid clashes with major events (political, sporting etc.)
  - Appropriate measures to cope with demonstrations etc.
- Public Relations – main areas of risk
  - Dichotomy between openness and need to ensure security
  - Not all stakeholders will have the same approach – need to coordinate

Lessons learned

- Always allow sufficient time for development and licensing
  - and then add a margin on top
- Close coordination throughout the whole project, ESPECIALLY with
  - Suppliers
  - Regulators
  - Civil authorities (national and /or local government, police etc.)
  - Other utilities with common interests
  - Shareholders/investors
  - Public relations
- Have contingency plans in place to deal with unexpected challenges
  - Transport schedule must be flexible enough to deal with last minute delays

THANK YOU FOR YOUR ATTENTION