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講演メモ

Fast Breeder Reactor Development in Germany
-History and Outlook-

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Establishing the Contracting Parties for SNR-300

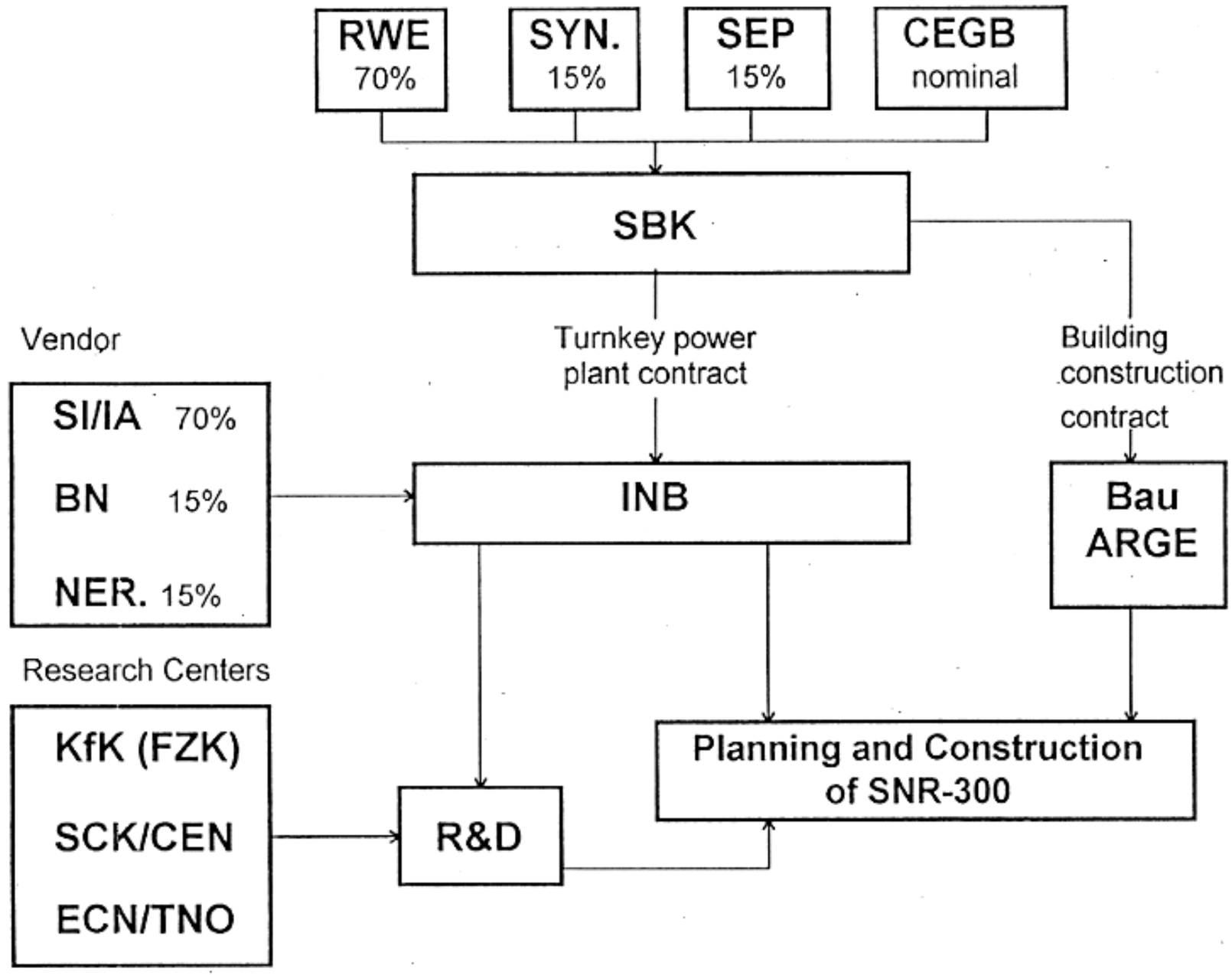
1965 Cooperation in fast reactor R&D among national research centers of Germany, Belgium and the Netherlands

1967 Exchange of Memoranda at government level on extending cooperation to the construction of SNR-300,
shares of financing and deliveries:

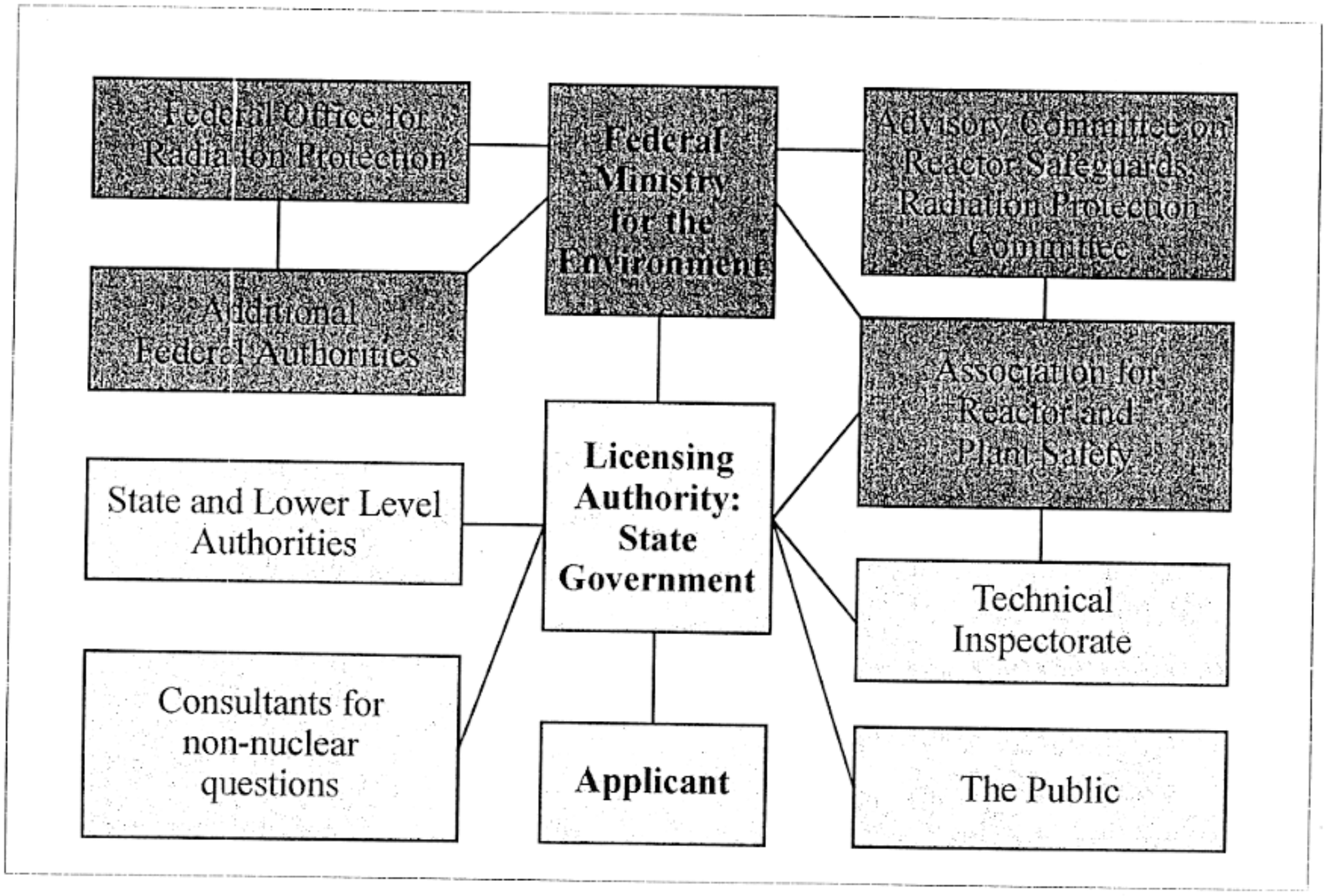
Germany	70 %
Belgium	15 %
The Netherlands	15 %

1968 Agreement of cooperation for development and construction of SNR-300 by
Siemens/Interatom (G)
Belgonucleaire (B)
Neratoom (N)

1969 Foundation of „Schnellbrüter-Kernkraftwerks-Gesellschaft“, leading members being:
RWE (G)
Synatom (B)
SEP (N)



Organization of the SNR-300 Project



Licensing Procedure for Nuclear Installations in Germany

Licensing Procedure for Nuclear Power Plants in Germany

(1) Principal concept permit on the basis of the Reactor Safety Report

(2) „Stepweise“ construction of the plant according to partial construction permits TG 7/1, TG 7/2, TG 7/3 . . . .

(3) With construction completed, licenses to be issued for
- pre-nuclear commissioning tests
- nuclear commissioning tests

(4) Preliminary license for operation

(5) Final license for operation

From Basic Design Studies to SNR-300

1965 - 67	Na-2 study as the design basis for SNR-300 (Karlsruhe in cooperation with Siemens/Interatom)
12/1969	SNR safety report submitted by SNR consortium; technical concept is changed decisively on request of the Advisory Committee on Reactor Safeguards (RSK) and the operators: - Kalkar instead of Weisweiler as site - Bethe-Tait accident to be considered - core catcher to be provided for - external impacts to be considered - outer containment to be rectangular - no breeding blanket, i.e. CR < 1
mid-1971	Presentation of a revised safety report
05/1972	Positive overall expert opinion by TÜV
06/1972	Final positive vote by the RSK
12/1972	First partial construction permit TG 7/1 is issued
03/1973	Start of construction

SNR-300 before the Federal Constitutional Court (BVG)

08/1977 TG 7/1 has been the subject of litigation before the Administrative Courts since 02/1972.
The Münster Higher Administrative Court has suspended proceedings on the grounds of seeking a rule by the BVG to find out whether Section 7 of the Atomic Energy Act, to the extent in which it enables permits to be issued for the fast breeder line, is compatible with the German Basic Law.

08/1978 In its ruling, BVG unanimously states that the breeder reactor is legally covered by the valid Atomic Energy Act.

04/1988 Because of a profound political crisis, the Federal Minister for Environment sends a letter of instructions to the licensing authority in NRW.
The state government responds by bringing action before BVG.

05/1990 The judgement of the Court is impressive in its clarity.
The result in a nut-shell: the action brought by the State of NRW is dismissed in all respects.

SNR-300 before the German Federal Parliament

12/1978 Federal Parliament agrees on continuing construction of SNR-300, but puts an important string to that decision: prior to commissioning, another decision by the Parliament is to be sought in a political debate.

In preparation of that decision, a Parliamentary Committee of Inquiry on „Future Nuclear Energy Policy“ is set up.

06/1980 After lengthy deliberations, the Committee accepts the development of breeder reactor technology „for research policy purposes“. This includes construction of SNR-300. The safety level of SNR-300 must not be inferior to that of a modern PWR.
Two studies are commissioned for further evaluations:

An „Upper Bound Study“, i.e. a literature survey on Bethe-Tait accidents with high mechanical energy releases (370 MWs or higher).

A „Risk-oriented Safety Analysis“ along the lines of the „German Nuclear Power Plant Risk Study“:

Both studies are to be conducted by scientists differing in their attitudes towards nuclear power.

SNR-300 before the German Federal Parliament (continued)

05/1981 The Committee is reconstituted by the next German Parliament.

05/1982 On the basis of the two studies, the Committee makes the following recommendations:

(1) Breeder reactor technology must be made available for the long-term use of nuclear energy. In the light of this aspect, commissioning of SNR-300 is important.

(2) The licensing procedure under the Atomic Energy Act for SNR-300 is carried out correctly and with great care.

(3) The risk arising from operation of SNR-300 is in the same bandwidth as that associated with LWRs now in operation.

(4) Commissioning of SNR-300 is recommended in several steps. Consequently, the parliamentary reservation should be lifted.

11 out of 16 members of the Committee vote in favor of these recommendations.

12/1982 The vote by the Parliament turns out a clear majority in favor of lifting the parliamentary reservation for commissioning SNR-300.

Turning Point and Upswing (1982 - 1985)

09/1982 TG 7/5 is issued. It covers mainly primary and secondary systems, reactor vessel and internals, reactor protection system, emergency diesels, and reventing system.

10/1982 Change in Federal Government from SPD to CDU coalition, the so-called „Wende“

12/1982 Positive decision by Federal Parliament on commissioning SNR-300.

12/1982 Negotiations by the new government help close the financial gap of the SNR-300 project.

Activities on the construction site:

end of 1984 Pressure test and leak rate test of the steel shell are completed successfully,
reactor vessel is moved to its final position.

1983 - 1985 All 33 large components arrive at the construction site and are installed on the spot.

end of 1983 Successful pressure test of the primary system.

end of 1984 Successful pressure test of the containment system.

mid-1984 Start of commissioning with delivery of first sodium volumes. In the subsequent pre-nuclear commissioning stage, sodium systems are cleared in a high-temperature clean-up step.

A Sodium Fire in SNR-300

11/1984 Some 200 kg of sodium are ignited on the roof of the reactor building, they accidentally have been carried upward through depressurization pipes from the basement of a steam generator building in the commissioning tests

The commissioning staff and the fire brigade on the spot are able to control the fire very quickly. Repetitions of the event are precluded by a technical modification in the secondary sodium system.

Decline and End I (1984 - 1986)

1984 Social Democratic Party (SPD), now the biggest opposition party in Federal Parliament, decides to opt out of nuclear fuel reprocessing, and to add no new nuclear power plants.

05/1985 State parliamentary elections in NRW again lead to an absolute majority for the SPD and consequently exacerbate the breeder debate. Farthmann, head of the SPD parliamentary group: „Do not kindle this hell fire"!

04/1986 Chernobyl accident

08/1986 SPD decides at its federal party convention to opt out of nuclear power within ten years.

mid-1986 Minister Jochimsen (SPD) surprisingly states at a press conference - before informing the applicant - that the preliminary positive overall assessment required for any permit can no longer be expressed for SNR-300. His assertions are:

(1) There were similarities between the Chernobyl reactor and the SNR-300.

(2) Earlier Bethe-Tait analyses were not reliable.

(3) Technical events in the pre-nuclear commissioning phase raised doubts about the quality status of the plant.

Decline and End II (1987 - 1991)

04/1987 Jochimsen (SPD) organizes another press conference to tell the public about his intention even to refuse the next partial construction permit, TG 7/6.

mid-1986 Status of SNR-300 reaches a 95 % level of completion. The attitude of the licensing authority leads to a deadlock. Federal Ministry for Research, BMFT, makes available interim funds to cover the „delay phase".

1988/89 A „holding phase" and an „extended holding phase" are defined till the end of 1991, and are financed one third each by BMFT, German utilities, and Siemens (necessary funds: 105 MDM/a)

04/1987 The letter of instructions to NRW by the Federal Minister for the Environment fails to make an impact. MWMT continues to act by „kalkarization according to the Letter of the Law".

03/1991 Financial problems have become more and more urgent. Successful completion of the licensing procedure no longer is to be expected. To avoid additional costs, BMFT, utilities, and Siemens, in accordance with the rules of the holding phase agreement, decide to provide no more funds. This is the end of the SNR-300 project.

A press release by BMFT succintly notes: The responsibility for the end of Kalkar, thus the participating utilities, the vendor, and BMFT, clearly lies with the State of North Rhine-Westphalia

Comments by the German Advisory Committee on Reactor Safeguards, RSK

04/1987 RSK duly investigates the comparison of the RBMK-1000 Chernobyl reactor with SNR-300. It finds major differences between the two reactors in nearly all design aspects.

This is true especially for the reactivity behavior: SNR-300 is characterized by its good controllability, while RBMK-1000 shows unstable behavior and complex physical dependencies. In all major safety-related respects, such as redundancy, diversity, level of automation, and safety margins, the protection and scram systems of SNR-300 are found to be clearly superior.

09/1987 RSK organizes a special meeting on the Bethe-Tait accident, attended by national expert consultants and international experts. The international experts agree that Bethe-Tait accidents of the type discussed for SNR-300 are attributed to the residual risk in their countries.

They also confirm the experimental verification of the SAS 3D code used to treat the initiation phase. With regard to recriticality accidents, RSK experts state that its mechanical energy potential remains far below the design level of 370 MWs.

Escalation of Costs

1969	Estimatd costs	670	MDM
11/1972	Contract price	1,535	MDM (without Pu inventory)
1975		3,200	MDM
		(1,100	MDM price escalation)
1982		6,050	MDM
		(2,100	MDM price escalation)
1991	end of project	ca. 7,000	MDM
		(ca. 3,000	MDM price escalation)

Conclusions

Responsibility for the licensing of nuclear installations in Germany is with the State Authority - in case of SNR-300: North Rhine-Westphalia; the State Government leads the whole licensing procedure.
Federal Authorities can only give general instructions - in case of SNR-300: the Ministry for Environment and Reactor Safety.

Political intention of SPD and the SPD-ruled state of NRW was not obeying to the instructions given by the Federal Authority, and was not following judgement of the Federal Constitutional Court.

The strict politically motivated application of

- enlarging the request for more and more analysis and experiments for so-called critical licensing questions,
- the use of so-called independent (not scientifically accepted) reviewers,
- the questioning of the scientific and technical reliability of the designer (Siemens/Interatom),
- the delaying of the licensing procedure by filing suit at administrative courts by interveners

led to a practical deadlock of the project and ever increasing costs also for industry.

Abandonned Nuclear Projects after the German Reunification

THTR-300	**1990**
SNR-300	**1991**
Greifswald	**1990**
4x440 MWe VVERs in operation, 4x440 MWe VVERs under construction	
Stendal	**1990**
2x900 MWe VVERs under construction	
Hanau MOX plant	**1996**

Aims of Fast Breeder Development

Before the mid - 1970s

General aspects:

- **high introduction rate of nuclear power in the world**
- **expected limitations in uranium fuel supply**

Consequences:
Realisation of high breeding ratios in order to equip first core of additional breeder reactors with plutonium.

After the mid - 1970s

General aspects:

- **slower introduction rate of nuclear power in the world**
- **availability of large amounts of plutonium from reprocessing of spent LWR fuel**

Consequences:
Deployment of fast breeders to be postponed into a far distant future. Use of fast reactors to be considered as Pu burners.

Main Objectives for Fast Breeder Reactors (FBRs)

- FBRs burn uranium-238 or thorium-232
  (high plutonium or U-233 inventory in reactor or fuel cycle)

- Excess plutonium production of FBRs: 80 - 150 kg Pu per GWe·a

- Uranium consumption of FBRs: 1.2 - 1.4 t U-238 per GWe·a

- With almost infinite resources FBRs compete with D-T fusion reactors
  - not with other fission reactors (LWRs, AGRs)

- **Fast reactors can use "dirty" plutonium of LWRs after several recycling steps (i.e. 50% Pu-fiss or less) either as burner or as breeder reactors**

- **Fast burner reactors without blankets but with diluent assemblies can burn**

  ≈ 600 kg Pu per GWe · a
  ≈ 140 kg Np per GWe · a
  ≈ 80kg Am per GWe · a

  (5% additional enrichment of Np in fast reactor cores is feasible with regard to safety features)

Modern Safety Features of Fast Breeder Reactors

Strong improvement of inherent safety:

- **Expansion of the control rod linkage (temperature increase → negative reactivity)**

- **Self shutdown capabilities in case of:**

  - loss of primary coolant pump power

  - loss of tertiary heat sink (heat exchanger)

- **Fast reactor shutdown after total loss of tertiary heat sink. Stabilization at 600 - 650 °C.**

- **Fast reactor shutdown after total failure of external electricity supply to primary coolant circuits. Stabilization at 600 - 650 °C.**

Decay heat removal in both cases through natural convection to the atmosphere via Na-air-heat exchangers.

CAPRA Programme

(Consommation accrue de Pu dans les Rapides)

Objective: Feasability study to burn Pu and minor actinides in optimized fast reactors

Participants:
- CEA
- AEA/BNFL
- EFRA (Novatome, Siemens, NNC)
- ITU
- KfK

Main topics:
- fuel studies
- core physics and design
- core safety
- irridation experiments

CAPRA - Phase I

Programme launched by CEA in 1993

First step: Feasibility study

Requirement: Fast reactor with high burning rate of Pu and minor actinides

Criteria:

- oxide fuel with high Pu content
- high power core (1500 MWe)
- compatibility with conventional steam supply system
- use of recycled (degraded quality) Pu
- uranium-free fuel types (optional)

After the End of SNR-300 (1991 - 1997)

Research Center Karlsruhe cooperates with French CEA and British AEA in

CAPRA Programme

German utility continues 16 % participation in French SUPERPHENIX

Nuclear Energy in Germany

Government Policy:

22 GWe ==> 35 % of electricity generation based on PWRs and BWRs

In 1994 Amendment of Atomic Energy Law:

for future reactors: no evacuation of population outside the plant site in case of core melt accidents

European Pressurized Water Reactor (EPR) designed by Siemens/Framatome according to this safety goal

Advanced BWR-1000 design by Siemens according to this safety goal

In 1994 amendment of the Atomic Energy Law:

- reprocessing and waste disposal,
- direct spent fuel disposal

are equivalent measures in the future

Intermediate spent fuel and storage facilities are available (Ahaus and Gorleben)

Waste disposal site for low and intermediate waste:

Konrad mine

HAW from reprocessing and direct spent fuel elements:

Gorleben salt mine

MOX fuel for Pu burning:
Almost all PWRs and BWRs in Germany are licensed to use up to 50 % MOX fuel elements in the core
MOX fuel will come from French MELOX plant after Hanau MOX plant was abandonned

Proliferation

- Germany signed NPT around 1970
- Participated in INFCE 1978–1982
- All nuclear facilities are subject to
  - IAEA safeguards inspection
  - EURATOM safeguards inspection
  - State nuclear material inspection
- Proliferation questions had no influence on decision for
  - SNR–300 termination
  - Reprocessing plant termination
  - MOX fuel fabrication termination
- Pu recycling avoids Pu mine build–up by direct spent fuel