TWG-FR/140

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Meeting of the Technical Working Group on Fast Reactors (TWG-FR)
(41st Annual Meeting)

IAEA Headquarters, Vienna, 26 – 29 May 2008

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2008

1. Introduction

The 41st Annual Meeting of the Technical Working Group on Fast Reactors (TWG-FR) was held from 26 – 29 May 2008 in Vienna at IAEA Headquarters.

The meeting was attended by the TWG-FR Members and Advisers from the following Member States (MS): Belarus, Belgium (observer), China, France, Germany, India, Italy, Japan, Kazakhstan, the Republic of Korea, the Russian Federation, Switzerland, the United States, and the International Science and Technology Center (ISTC). Apologies for not being able to participate were received from Brazil, the United Kingdom, the European Commission, and OECD/NEA.

Mr. J. Rouault, from France (CEA), was appointed chairman.

The objectives of the meeting were to:
- Exchange information on the national programmes on Fast Reactors (FR) and Accelerator Driven Systems (ADS)
- Review the progress since the 40th TWG-FR Annual Meeting, including the status of the actions
- Consider meeting arrangements for 2008, 2009, 2010 and beyond.
- Review the IAEA’s ongoing information exchange and coordinated research activities in the technical fields relevant to the TWG-FR (FRs and ADS), as well as coordination of the TWG-FR’s activities with other organizations and international initiatives
- Discuss future joint activities in view of IAEA’s Programme and Budget Cycles beyond 2008–2009.

2. Presentation and Discussion of FR and ADS Developments in the MSs

The participants made presentations on the status of the respective national programmes on FR and ADS development. A summary of the highlights for the period since the 40th TWG-FR Annual Meeting is given below:

Belarus

In 2005, the total consumption of primary fuels in Belarus amounted to 37051×10^3 tce that was 1054×10^3 tce (or 2.9%) higher than in 2004. This growth was mainly covered by increased use of domestic and renewable energy resources (their consumption grew by 419.1×10^3 tce, or 14.7%), as well as of natural gas (its consumption grew by 457.7×10^3 tce).

In Belarus, fuel consumption for electricity and heat generation makes up the largest share of primary energy consumption. In 2005, it amounted to 27.3×10^6 tce, which was higher than in 2004 by 0.3 million tce, or 1.1%

The following table provides the details of the primary energy resources in Belarus (10^3 tce)

Energy Flows,	2004	2005
Domestic primary energy recourses	5192	5362
Import	51054	53166
Non-CIS countries	723	114
CIS countries(excluding the Russia)	50331	53052
Russia	50319	53041
Export	20172	21634
Non-CIS countries	19113	20913
CIS countries(excluding the Russia)	1059	721
Russia	782	13
Stock Changes	-77	157
Total Primary Energy Consumption	**35997**	**37051**

At the YALINA subcritical facility of the Joint Institute for Power&Nuclear Research-Sosny (Minsk, Belarus), experimental and theoretical investigations of the neutronics and kinetics for Accelerator Driven Systems have been performed within the framework of State Scientific Programs, the ISTC Project B-1341, and the IAEA Coordinated Research Projects “Calculation benchmark on neutronics of a booster (cascade) assembly driven by external neutron sources” and “Analytical and Experimental Benchmark Analysis on Accelerator Driven Systems”, as well as the “Low Enriched Uranium Fuel Utilization in Accelerator Driven Subcritical Assembly Systems” collaborative wiork.

The YALINA facility consists of a deuteron accelerator, a target unit, and subcritical booster assembly with thermal and fast neutron spectra. The assembly consists of a central Pb zone (fast zone), a polyethylene zone (thermal zone), a radial graphite reflector and a front and back biological shield of borated polyethylene. The fast-spectrum Pb zone and the thermal-spectrum polyethylene zone are separated by a neutron buffer zone consisting of one layer with metallic natural uranium and one layer with boron carbide which is located in the outermost two rows of the fast zone. Thermal neutrons diffusing from the thermal zone to the fast zone will either be absorbed by the boron or by the natural uranium, or transformed into fast neutrons through fission reactions in the natural uranium. In this way, a coupling of mainly fast neutrons between the two zones is maintained. The facility is equipped with different experimental capabilities and support systems. Monitoring the system subcriticality during operation is a vital issue for an ADS, and the main question is how it should be performed. The YALINA experimental and analytical investigations for monitoring the subcriticality level during the fuel loading and start up, as well as the transmutation rates of some long-lived radioactive nuclides, have been performed in the original configuration YALINA-Booster assembly. This configuration has metallic uranium with 90% enrichment and uranium oxide with 36% enrichment in the booster zone, and uranium oxide with 10% enrichment in the thermal zone. These studies are being continued in the new configuration of YALINA-Booster, which replaces the 90% enriched fuel in the inner part of fast zone with uranium oxide with 36% enrichment.

Belgium

The Belgian activities in the field of “Fast Reactors & Accelerator Driven Systems (ADS) – Technical Working Group on Fast Reactors“ are mainly related to ADS and in particular to the MYRRHA project development. MYRRHA is an accelerator-driven, multi-purpose fast neutron spectrum facility for R&D, cooled by a lead-bismuth eutectic.

The evolution of MYRRHA has been presented extensively in recent annual meetings of the TWG-FR and in particular (May 2004) the spallation target and our collaboration network, (May 2005) the core management, the primary systems design and the safety analysis, (May 2006) the results obtained in the FP6 framework (IP_EUROTRANS project) and the perspective for implementation and finally (May 2007) a detailed comparison between the "Draft-2" design obtained in 2005 and the current FP6 XT-ADS design.

Since 2007 the design has further progressed: reporting is underway for the XT-ADS primary systems, core design and plant layout (among others); safety studies and cost evaluation may start now that the design is “frozen” and in parallel a comparison exercise has started with JAEA between the two large-scale machines (a joint workshop has also been organised at FZK in February this year).

But there is more to report than just design activities:

— SCK•CEN is also deeply involved in the coupling GUINEVERE experiment (also within EUROTRANS). GUINEVERE consists of the coupling of a deuteron GENEPI-3C accelerator (provided by CNRS) able to function in different modes (continuous, pulsed and beam trip), with a titanium-tritium (Ti-^{3}H) target installed in a lead cooled, fast sub-critical multiplying system (U-metal fuel rodlets provided by CEA). GUINEVERE is scheduled to be operational at the end of the EUROTRANS project (now March 2010);
— R&D experiments for material and fuel studies are running, within or outside EC financing (like the WEBEXPIR experiment presented last year);

SCK•CEN have made a proposal (called “CDT”) for the “after FP6” programme. The objective of CDT is to produce an advanced design of a fast spectrum experimental facility (FSEF) working either in sub-critical mode (ADS) or in critical mode. CDT includes also the set-up of a centralised, multi-disciplinary team, based for the core group at the Mol-site. The partners of the project come from both industry and research organisations. The proposed project is scheduled for three years (2009 – 2011).

China

China’s energy demand

Since the end of 1970’s, China’s national economy has been in a stage of continuously stable development. During the past five years, the average growth rate of the National Gross Domestic Products (GDP) was 9.4%, as shown in Table 1. The economy development was supported by the energy production with a corresponding growth. The annual primary energy consumption for the period of 2001-2005 is also shown in Table 1.

Table 1 National Economy Development in China

Year	2001	2002	2003	2004	2005
GDP Annual Growth Rate (%)	8.0	9.1	10.0	10.1	9.9
Annual Primary Energy Consumption (Billion tce)	1.43	1.52	1.75	2.03	2.23

The share of the different primary energy consumption sources in the year 2005 (adding up to 2.23 billion tce) is shown in Table 2.

Table .2 Primary Energy Consumption in 2005

Energy Type	Consumption	Growth rate from 2004
Coal (billion t)	2.14	10.6%
Oil (billion t)	0.3	2.1%
Gas (billion m^3)	50	20.6%
Hydro (TWh)	401	13.4%
Nuclear (TWh)	52.3	3.7%

China's energy security is facing two major challenges. The first one is the contradiction between the ever increasing demands of the country's energy and the insufficient reserves of fossil fuels. Presently, China's per capita energy consumption is only some 1.7 tce/a, which is about half of the world average. China's energy supply has to be increased significantly in the coming decades to meet with the requirements of the rapid development of the national economy.

The second challenge comes from the irrational energy structure, in which coal covers 60% of the primary energy and 75% of the power generation. The coal based energy structure causes serious problems of environmental pollution and emission of green house gases (GHGs). China has become one of the most polluted countries in the world. In the year 2000 as an example, China emitted 20 Mt of SO_2 and 3 Gt of CO_2, both ranked the world second highest. The country's economic loss due to environmental pollution accounts for 3 to 7% of the GDP. These problems would hinder the further development of the country if they could not be solved properly.

Among the alterative energy resources, hydro power resources, as the renewable and clean energy resources, are abundant in China and will be exploited with top priority in the coming years. In China, the economically exploitable hydro- power resource is estimated to be some 400 GWe. At present, the installed capacity of hydro-power is some 100 GWe.

Considering the fact that the oil and gas reserves on earth will be depleted in less than 100 years, we have to adjust from now on the energy structure in China, gradually reducing the sectors of coal, oil and gas and increasing the sectors of new energy resources.

The non-hydro renewable resources, such as wind, solar, biomass energies, are highly encouraged to develop (especially wind power). However, they could not replace the fossil fuels on a large scale in the foreseeable future owing to their low energy density, intermittent supply and high cost.

Considering the fact that the existing energy structure in China is based on fossil fuels (especially coal), China's near-term energy policy (before 2020) has to be dependant on coal as the major energy source while actively developing hydro power, nuclear power and other new energy resources and putting the top priority on improving the energy efficiency. This calls for the accelerated development of nuclear power, as fast as possible.

As a well-developed clean energy with zero discharge of GHGs, nuclear energy has received more and more attention in China and is regarded as a big supplement to the fossil fuels together with the hydro power. There is big room for the development of nuclear energy in China. Nuclear Energy will be one of the major energy sources in the coming 50 years in China.

With the rapid growth of the national economy, it is expected that by the year 2020 China's power capacity would be increased from the present 400GWe to some 960 to 1000 GWe (at least 560 GWe increase). To solve the problems of the ever increasing demand - supply incongruity, China's near term policy has to depend on coal as the major energy source while putting the top priority on improving the energy efficiency. So, more than half of the 560 GWe increase will be contributed by coal-fired power, and the installed capacity of hydro-power would be increased by more than 170 GWe. Even then, there is still a big gap to be filled. This calls for the accelerated development of nuclear power as fast as possible. China's national goal by 2020 is that the nuclear power capacity will be increased from the present 9 GWe to 40 GWe in operation with another 18 GWe under construction. The nuclear share will be some 4% of the nation's total power capacity by 2020.

After 2020, it is predicted that China's domestic supply of oil and gas will drop down and will have to be mainly dependent on import; the larger scale use of coal will be limited by the environmental burden (the highest scale of coal burning should be less than 3.4 Gtce/a); and that there will be no big room for further expansion of hydro-power after its capacity reaches 300 GWe owing to the country's limited economically exploitable hydro resources (<400GWe). The other renewable resources (such as wind and solar energy) will be fully encouraged to develop and will play an increasing role, especially in some remote or coastal areas. But it will be unlikely that the renewable energy resources could replace the fossil resources on a large scale in the foreseeable future. The major way to meet the energy demand after 2020 is thus to further increase the share of nuclear energy so as to ensure both the energy security and environmental safety of the country.

By the mid of 21st century, the capacity of nuclear power in China should reach about 240 GWe or even higher with its share up to 15% of the total power capacity. Nuclear power will then be one of the three major energy resources in China together with clean coal and hydro-power. Nuclear energy will make greater contributions to China's sustainable development.

Nuclear energy development strategy

In line with the worldwide trend of nuclear power development and the ever increasing energy demand in China, it is necessary to develop advanced nuclear energy systems in China. Considering the nuclear energy as a systematic engineering, China will develop and deploy the advanced pressurized water reactor (PWR) nuclear power plants (NPPs) in the coming 30 years or so and fast reactor (FR) power plants, together with the development of the associated nuclear fuel cycle technologies, so as to meet the requirements of the sustainable development of the nation's economy and environment.

For the sustainable nuclear energy supply, the stepwise introduction of thermal reactors - fast reactors - fusion reactors has been decided as a basic strategy in China. For nuclear fission energy, the fast breeder reactors will play a role in the efficient use the uranium resources, fast burner reactors will transmute the minor actinides (MAs), and with the more efficient dedicated burner ADS the volume and toxicity of the high level waste which needs geologic disposal will be minimized.

As mentioned, China needs about 240GWe nuclear capacity by 2050. For such huge capacity it is impractical to use only PWRs to meet it, since this translates into uranium needs of about 2.4 to 2.5 million tons for 60 years of operation. Although China is, theoretically, abundant in uranium resources, the technically feasible and economically affordable explored uranium reserves are limited. Moreover, worldwide, the reliable uranium reserve at prices lower than US$130/kgU are estimated at about 4 to 5 million tons.

For the nuclear power development, the following two very important statements have been made in the document of the “National Mid-Long Term Science and Technology Development Program (2006-2020)” issued by the State Council of the People’s Republic of China on 9 February 2006: (1) “…to energetically develop the nuclear power technology and to form a R&D capability of our own on nuclear power technology…”, and (2) “…the advanced nuclear energy system G-IV, nuclear fuel cycle, and fusion energy technology are paid more attention …” In accordance with this programmatic document, the Government has decided to develop continuously nuclear power with the above mentioned mid-term (2020) target of 40 GWe. The Government has approved 4 new NPPs with 8 PWR Units. Other 30 NPP units on 7 sites are programmed.

The sustainable development of nuclear power depends on the full utilization of uranium resources and the minimization and proper disposal of nuclear waste. Considering the fact that the economically exploitable uranium reserves in the earth crust are limited (as mentioned, 4 to 5 million tons at the cost <130 US$/kg), sustainable development of nuclear fission energy depends on the fast breeder reactor (FBR) energy system, which is based on the closed fuel cycle. China’s nuclear energy development will follow the way of thermal reactor system – fast reactor system gradually. It is estimated that at least 30 years are needed for the commercialization of the FBR energy system in China.

The FBR development is still in the early stage, marked by the China Experimental Fast Reactor (CEFR) which is under construction right now. According to the strategy study on the fast reactor development in China, taking into account the complexity of this technology, and based on the experiences of fast reactor development in the world, the fast reactor engineering development in China will be divided into three steps (see also Table 3): (1) China Experimental Fast Reactor (CEFR); (2) China Demonstration Fast Reactor (CDFR), and (3) China Commercial Fast Reactor (CCFR).

Table 3 Possible China FBR Development Strategy

Step	Reactor	Power (MWe)	Start of Design	Commissioning
1	CEFR	25	1990	2009
2	CDFR	800 - 900 (to be determined)	2010	~2017
3	CCFR	⩾1000	not determined	2025~2030

There are two possibilities in the third development stage:

(1) If the natural uranium is not sufficient to support new PWR constructions and the large CCFR has not yet reached the desired development stage, several CDFR units will be built as “commercial nuclear power plants”.

(2) If the development of the CCFR is proceeding according to plan, the CCFR will be built as the standardized commercial nuclear plant based on China's demand of nuclear energy.

The CCFR with high breeding capability will be deployed based on the experience with CEFR and CDFR. In order to (1) limit the expenses for research, development and demonstration of some key technological features, to (2) facilitate more efficient validation and verification of design software such as computer codes, and finally, to (3) decrease the technical and economic risks of fast reactor engineering development, the continuity of some of the main technical design choices of the Chinese FBRs has been suggested, as shown in Table 4.

Table 4 Technical Continuity of Chinese FBRs

	CEFR	CDFR	CCFR
Power MWe	25	800 - 900 (to be determined)	⩾1000
Coolant	Na	Na	Na
Type	Pool	Pool	Pool
Fuel	UO_2 MOX	MOX Metal	MOX Metal
Cladding	Cr-Ni	Cr-Ni, ODS	Cr-Ni, ODS
Core Outlet Temp ºC	530	~550	~500
Linear Power W/cm	430	450 - 480	450
Max.Burnup MWd/kg	60 - 100	100 - 120	120 - 150
Fuel Handling♣	DRPs SMHM	DRPs SMHM	DRPs SMHM
Spent Fuel Storage♦	IVPS WPSS	IVPS WPSS	IVPS WPSS
Safety♥	ASDS PDHRS	ASDS+PSDS PDHRS	ASDS+PSDS PDHRS

♣DRPs: Double Rotating Plugs
SMHM: Straight Moving Handling Machine
♦IVPS: In-Vessel Preliminary Storage
WPSS: Water Pool Secondary Storage

♥ASDS: Active Shut-Down System
PSDS: Passive Shut-Down System
PDHRS: Passive Decay Heat Removal System

As for the related the fuel cycle, a 50 t/a PWR spent fuel reprocessing pilot plant and a 500 kg/a MOX fabrication line are under construction. Projects for an industrial reprocessing plant and for a MOX fabrication plant are under the application phase.

France

The French Energy Policy

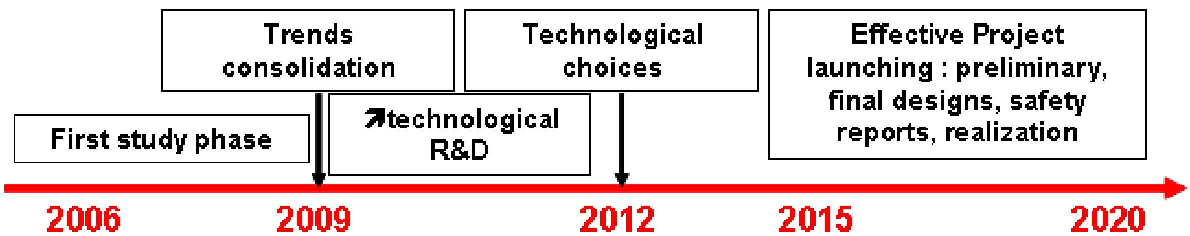
In France the development of an ambitious nuclear power program associated with a closed fuel cycle was driven by the political will to achieve a substantial level of energy independence in a country poorly endowed in fossil fuels and having domestic uranium resources available in limited amount. According to the 2005 law establishing guidelines for France energy policy and security, the government makes sure that Nuclear Power provides an important share of the electricity mix. To maintain the nuclear option opened after 2020, a new generation reactor must be available by 2015 on a commercial basis. For this reason, the construction of an EPR is being started at Flamanville for operation in 2012. With the Finnish EPR at Olkiluoto, these are the two first units of a standardised new family of GENERATION III reactors. The first GENERATION IV prototype is to be built by 2020. Industrial implementation is expected by 2040.

In addition, a status report was submitted to French authorities in 2005 at the end of the 15 years duration of the French Waste Management Act of 1991. As a result, the legal framework for the waste management in France was updated with two important laws, both enacted in 2006, specifically

— The Law on nuclear transparency and security established a new independent safety authority ASN (Autorité de Sûreté Nucléaire), chaired by a college of 5 members appointed for 6 years; and
— The Programme Act on the sustainable management of radioactive materials and wastes, which defines three roadmaps concerning radioactive waste and other radioactive substances, i.e. (i) reduction of quantity and toxicity, (ii) interim storage of radioactive substances and ultimate waste, (iii) deep geological disposal.

Future Energy systems strategy in France

In March 2005, an inter-departmental committee stated that France should study Sodium Fast Reactors (SFR) and Gas Fast Reactor (GFR) for the long term deployment of its nuclear fleet, together with Hydrogen production using high temperature reactors. In January 2006, the French president requested for the design of a generation IV system to be operated by 2020. In June 2006, the already mentioned law on the sustainable management of wastes included the necessity to study by 2012 the industrial prospects of GEN IV and ADS systems for minor actinides transmutation and to perform a pilot demonstration in 2020. This law introduces therefore a very strong link between reactor and waste transmutation studies. Finally, in December 2006, a second inter-departmental committee focussing on Fast Spectrum Systems agreed on a technical roadmap for SFR as a reference, GFR as an alternative, and their associated fuel cycle studies leading in 2012 to gather data to choose future options, as outlined below:



Gas Cooled Fast Reactors(GFR)
The GFR is a promising concept which combines the benefits of fast spectrum and high temperature, using helium as coolant. A status on the GFR pre-viability has been made at the end of 2007, ending the pre-conceptual design phase. This analysis represents an essential step before the next main project milestone related to the GFR viability, scheduled in 2012. A first consistent overall system arrangement has been proposed, based on a preliminary design of the main components, covering fuel, core, energy conversion systems, safety systems, and reactor integration.

The GFR R&D program is in progress with no showstopper still identified. The next step is the viability report at the end of 2012 to decide the next step.

Sodium cooled Fast Reactors
A coordinated research program between the CEA, AREVA NP and EDF has been defined and launched in 2007. It is organised according to the general schedule shown above. The program comprises four main domains of innovation:

1. An efficient core with enhanced safety: study and develop a reactor core that has significant advances in safety while limiting to the minimum the quantity of natural uranium used. The fuel will have the capacity to reach high burn-up and to transmute minor actinides. It will be easy to recycle it.
2. Resistance to severe accidents and external hazards: to enhance the resistance to severe accidents through the design of the fuel sub-assembly and the core catcher and to produce a safety demonstration more robust, that is to say covering a wide range of anticipated accidents. In the mean time, the resistance to external hazard, for instance a seismic impulse, will be re-enforced through the core and the containment designs.
3. An optimized power conversion system to reduce the sodium risk: alternative fluids are looked at to suppress the sodium water interaction risk, either liquid or gas. Where water is replaced by gas as a working fluid, standard gas or supercritical CO2 are looked at. Heat exchangers optimization is part of the program, the design of a compact component coupling intermediate heat exchanger and steam generator being the ultimate way to innovate.
4. Reactor design re-examination: discuss design options for the reactor and its components to facilitate inspection, maintenance, availability and dismantling, to reduce environmental impact and increase resistance to proliferation, to enhance performance and global economy. This includes a comparison of pool and loop type reactors, the impact of unit power and modularity. Fuel handling is considered as an important feature for the availability of the plant. Innovative techniques for in sodium inspection and repairing are developed.

Conclusion
The SFR R&D program has been elaborated with the objective to explore through several new pre-conceptual designs some innovations that could improve the system on the safety, the economic competitiveness, Sustainability and capacity for long-lived waste transmutation.

The GFR system is promising (first results confirm the potential of the concept) and requires significant breakthroughs in the field of fuel, materials and system arrangement. Some common R&D interests with the SFR are emerging.

The next steps are not the same for SFR and GFR: for SFR, construction of a prototype in the range 250 – 600 MWe to demonstrate economics and safety of new options, to be commissioned in 2020, subsequently to the selection of the main options in 2012. For GFR, an experimental reactor, ETDR, in the range of 50 MWth to demonstrate viability of key GFR technologies is planned to be possibly a European project in 2020.

India

IGCAR presented the main status report on FBR programme including Prototype Fast Breeder Reactor (PFBR) and BHAVINI highlighted the construction status of PFBR. BARC presented the status of ADS development in India.

The current installed capacity as of March 2008 is 143 GWe, of which nuclear power is 4.12 GWe. Fifteen thermal reactors are in operation and overall capacity factor achieved during financial year 2007-08 is 56%. Six nuclear power plants are under construction including PFBR. Beyond PFBR, it is targeted to construct four more FBRs of 500 MWe capacity by the year 2020. The pre-project activities for FBR-1&2 (twin unit concept) at Kalpakkam will commence during the current financial year. The future FBRs will have many innovative features to improve economy and enhance the safety.

As far as Fast Breeder Test Reactor (FBTR) is concerned, the 14th irradiation campaign completed during this period, is very impressive in terms of experiments conducted which were of relevance to PFBR and the life extension of FBTR. The non-stop operation of the reactor along with TG for 72 days is commendable. It is planned to plug three tubes in SG module from each secondary loop to achieve the nominal temperatures with the present small core and continue the irradiation of PFBR test fuel to its target burn-up of 100 GWd/t in the next three campaigns. Seismic re-evaluation of the plant is in finishing stages. The reactor will be available for another 20 years for various R&D activities related to fuels and materials.

Regarding PFBR, the design and analysis of remaining major systems and components have been completed during this period. This includes special subassemblies such as diluents and purgers, complementary shielding on the top shield, top shield cooling system, top shield platform, bearings for rotatable plugs, component handling flasks, etc. Many activities were completed towards construction of PFBR such as resolving issues raised by industries and construction groups on day to day basis, design review of handling and transport structures, providing guidelines for the assembly and erection of components, etc. R&D works in the fields of reactor physics, component development, thermal hydraulics, structural mechanics, materials & metallurgy, safety, fuel chemistry and reprocessing are focused towards future FBRs. The construction of PFBR is progressing well. The civil construction of nuclear island buildings is at an advanced stage and nearing completion. The construction of reactor vault has been completed achieving very high quality and dimensional tolerances. The reactor vault is ready to receive the safety vessel. The manufacture of safety vessel, thermal baffle, thermal insulation panels, sodium storage tanks, argon buffer tanks, core catcher and core support structure has been completed. The manufacture of main vessel is nearing completion and integration of core catcher and core support structure with main vessel will be taken up shortly. All the nuclear components are being manufactured to very high levels of tolerance and quality control. The project has achieved an overall physical progress of 34% as on 31st March 2008.

For closing the fuel cycle, a Fast Reactor Fuel Cycle Facility (FRFCF) is under construction at Kalpakkam. The layout of FRFCF has been planned in such a way that expansion is possible to meet the requirements of two more 500 MWe FBRs, which are planned to be built at Kalpakkam site at later date. The initial fuel requirement for PFBR will be met from the Pu obtained from the thermal reactors.

ADS activities in India are progressing in a de-centralised mode on 3 main sub-systems. BARC takes lead by focusing on activities of sub-critical reactor physics calculation codes, development of experimental validation, simulation studies of spallation target reaction and construction of LBE process system for thermal hydraulics & materials tests. These solutions have provided tools for conceptual design of a demonstration ADS in MW range of fission power and using 0.5-0.6 GeV proton beam at fraction of mA average current. High current proton accelerators accelerator's 20 MeV front end development is a project activity that is in progress at BARC. Main subsystems and the building are under construction. These include ECR ion source, radiofequency quadrupole (RFQ) & drift tube linac (DTL) along with their respective electrical power supplies. This phase of activities is estimated to be completed by 2012.

Italy

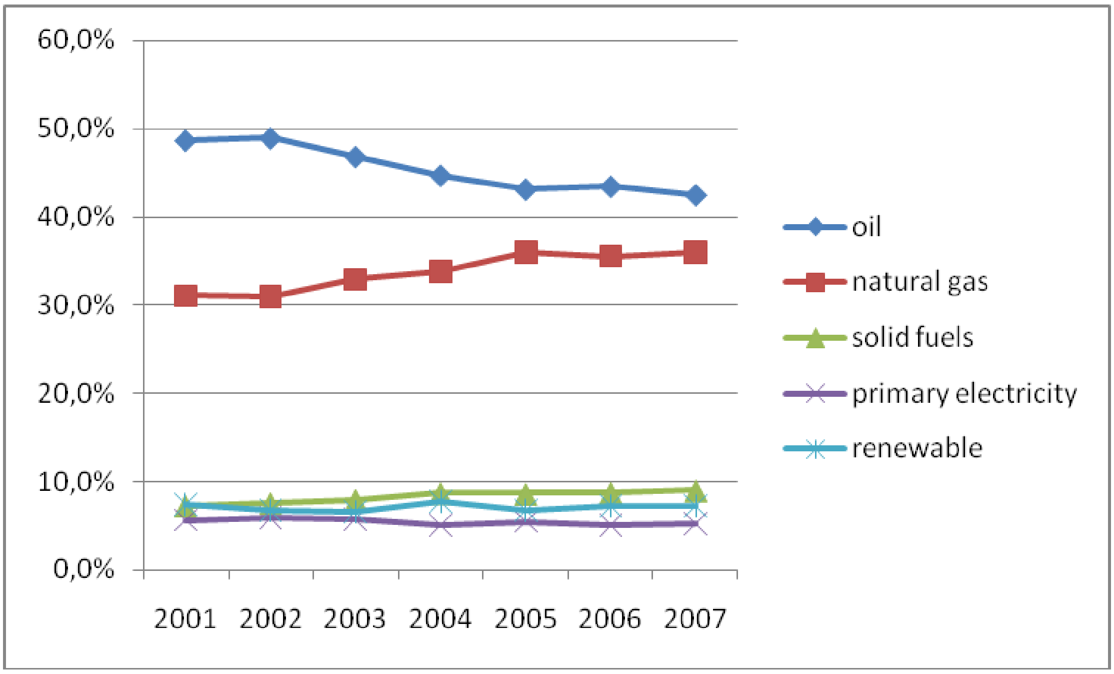
Italian Energy Balance

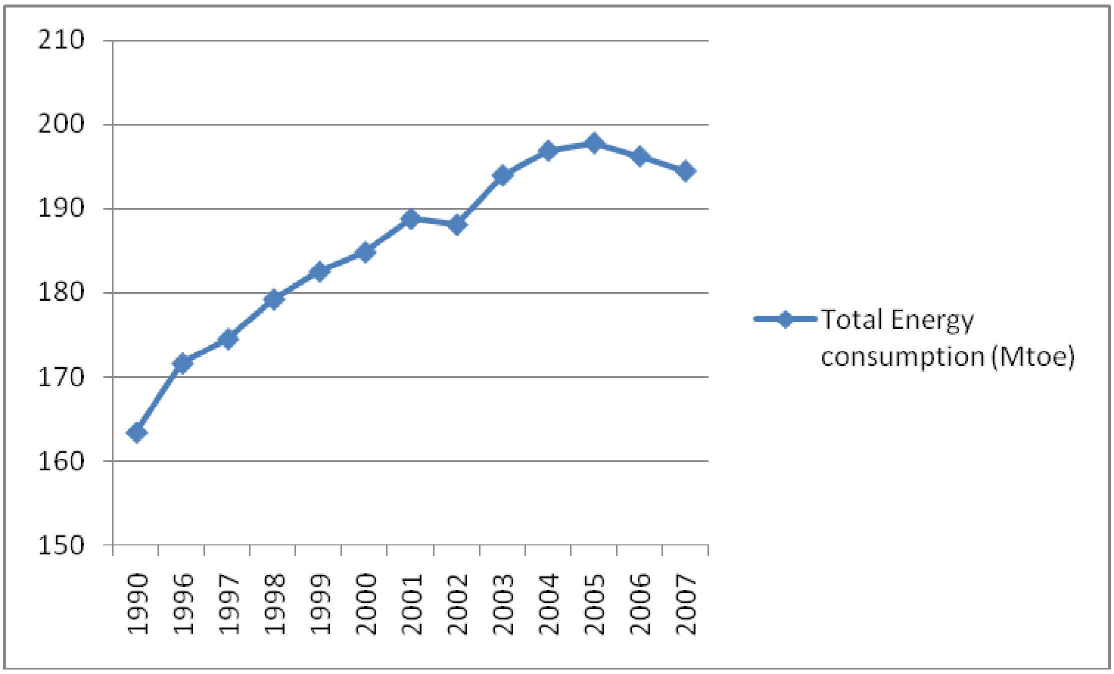
The summary of Italy's energy balance in the year 2007 is given in the two following tables. The first table here below shows the total primary energy consumption in 2007.

TOTAL PRIMARY ENERGY CONSUMPTIONS IN 2007
(temporary values)

	2007		**2007/2006 Δ %**
	Mtoe	**%**	
Oil	82,6	42,49	-3,08%
Natural gas	70,0	36,01	0,49%
Solid fuels	17,5	9,00	1,93%
Primary electricity	10,1	5,19	2,09%
Renewables	14,2	7,3	0,01%
TOTAL	**194,4**	**100,0**	-0,89%

Data going farther back is presented in graphical form in the following two figures. The first figure shows the trend in percentage terms for the various primary energy sources over the last years. In the second figure, the trend of total energy consumption in Italy is presented.

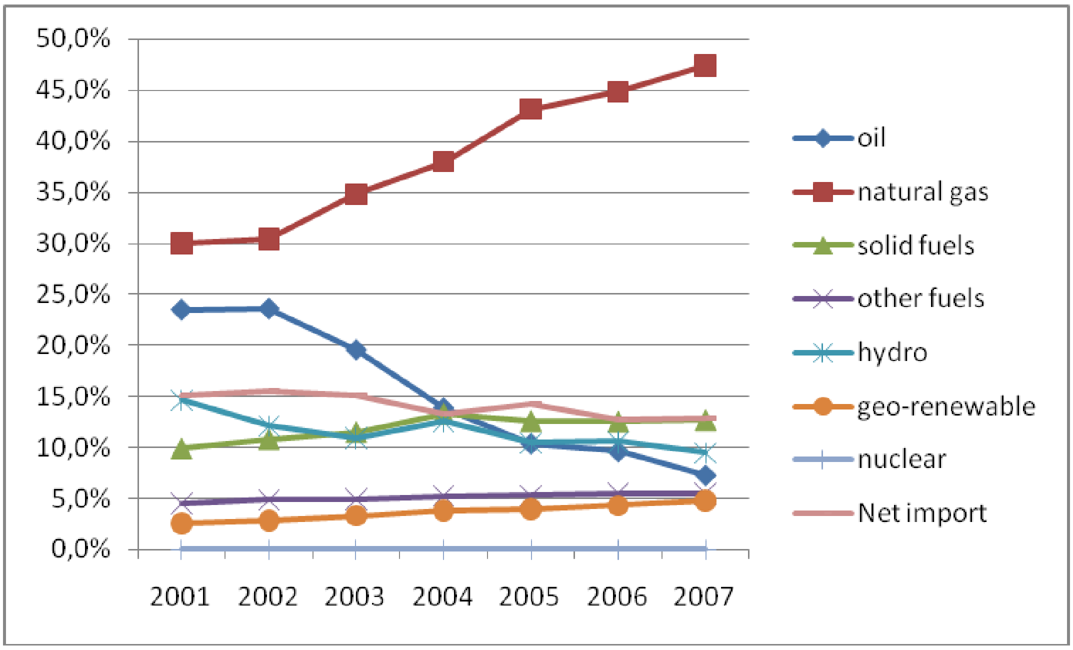




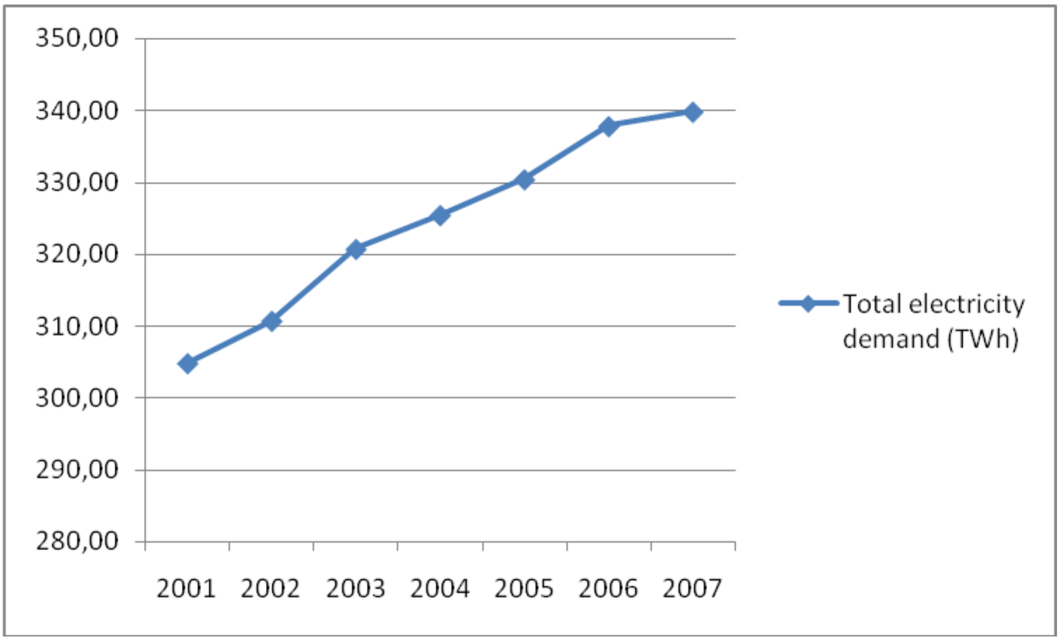
The second table here below shows the electricity generation and demand from various sources (and their variations with respect to the former year). The contribution of nuclear energy to the national electricity generation has been zero, while the net electricity import (45.9 TWh, i.e. about 12.94%) is essentially of nuclear origin.

ELECTRICITY GENERATION AND DEMAND IN 2007 (preliminary values)			
	2007		2007/2006 Δ %
	TWh	%	
Oil	25.8	7.27	-23.67
Natural gas	168.2	47.42	6.39
Solid fuels	45.0	12.69	1.81
Other fuels	19.3	5.44	0
TOTAL THERMAL	**258.3**	**72.82**	**1.13**
Hydro	33.5	9.44	-9.46
Geo-renewable	17.0	4.79	11.84
Nuclear	0.0	0.0	0.0
PRIMARY ELECTRICITY	**50.5**	**14.24**	**-3.26**
TOTAL GROSS GENERATION	**308.8**	**87.06**	**0.39**
NET ELECTRICITY IMPORT	**45.9**	**12.94**	**2**
TOTAL AVAILABILITY	**354.7**	**100**	**0.59**
GRID DEMAND	**339.8**		**0.71%**

The trend of the share of various primary energy sources is shown in the following figure.



The trend of the total electrical grid demand in Italy is shown in the next figure.



In 2007, Italy has increased the grid demand by 2.4 TWh, that have been provided by 1.2 TWh of domestic generation increase, by 0.9 TWh by increasing import and by 0.3 TWh by a reduced requirement for energy losses and pumping power.
Natural gas consumption for electric power generation increased also in 2007 by 6.39%, while the oil consumption decreased by 23.67% .It is worth underlining that the current electric power generated in Italy by natural gas has a share of 47.42%. This situation further reduces the flexibility of the national energy system, since nuclear energy is not contributing and the significant expansion of clean coal technology meets increasing difficulties.

General Overview of Italian Nuclear Energy Activities

In Italy nuclear activities are progressing mainly in the following fields:

- R&D is performed mainly by ENEA both in fission and fusion, and, more in general, in all others nuclear related fields, as well in the universities of Pisa, Roma, Palermo and in the Polytechnic Schools of Milano and Torino; these are the five universities entitled to graduate with slightly different denominations nuclear engineers.
- Decommissioning and waste treatment activities are performed by SOGIN and are progressing, even in the absence of a clear road-map for the national surface repository
- ENEL is expanding its acquisition of power plants abroad, including nuclear power plants and is building again a nuclear competence center
- The industry is involved in all above activities

The sharp increase in the cost of oil barrel, the respect of Kyoto protocol and the need to assure the strategic supply of energy are three strong elements in favour of nuclear energy. Recently concerns about global warming have increased and more favour is seen about nuclear energy as a massive source of carbon-free electrical energy. The new Government elected in the last April 2008 election has expressed many times its strong will of proceeding with the construction of new NPP's in Italy.
On his first day as Prime Minister, Silvio Berlusconi told the upper house of parliament that "*nuclear power, with all the necessary precautions, is today an*

indispensable option, not just for guaranteeing the energy needed for future development, but for safeguarding the environment we live in."
Economic Development Minister Claudio Scajola told on May 22, 2008:"*an action plan for a return to nuclear energy can no longer be avoided" "we must therefore rebuild skills and regulatory institutions, forming the necessary technical and entrepreneurial sector and providing credible solutions for radioactive waste*" "*during the term of this parliament, we will lay the first stone for the construction in our country of a group of new-generation nuclear power stations*".

A new consensus process about the choice of a national repository is going to be started by the Government. An expert Commission is working to define the roadmap an will conclude very soon its activities. This should lead to the opening of a national surface repository in a reasonable time and hopefully before 2018.

ENEA Activity Update
ENEA, the Italian National Agency for New Technologies, Energy and the Environment is a public undertaking operating in the fields of energy, the environment and new technologies to support competitiveness and sustainable development. Following the Bill n. 257 (September 3rd 2003) ENEA, which is heavily involved in Nuclear Fusion and Fission R&D activities, is responsible, at the national level, of the Scientific and Technological Presidium in the Field of Nuclear Energy.

As such, ENEA is partner of the SNF-TP (Sustainable Nuclear Fission - Technology Platform) project and member of the Sustainable Nuclear Energy Technology Platform (SNETP) launched by the EC in September 2007.

The ITER International Organization came into force as well as the European Domestic Agency Fusion For Energy (F4E, the European Joint Undertaking for ITER). F4E will take care of the fabrication of the component to be provided by Europe on the basis of the technical specification fixed by ITER IO. These events determine the actual starting of ITER construction and contribute to speed up the program with the aimed to shorten as much as reasonably possible the road toward DEMO. In this frame Italy is proposing a new Tokamak device to support ITER exploitation and to investigate some of the technology issue in view of DEMO. Other important elements of the program are the ‘ Broader Approach’ which is progressing: the design of the JT60 SA is currently under revision and the engineering validation phase of the activities IFMIF is going to start.

Finally, ENEA is participating in the US Global Nuclear Energy Partnership (GNEP) – whose Statement of Principles was signed by the Italian Government in November 2007 – being member of the working groups on: (i) Infrastructure Development; and (ii) Reliable Nuclear Fuel Services.

Nuclear Fission
(I) European Lead-cooled System (ELSY)
The ELSY (European Lead-cooled SYstem) project of the 6th European Framework Programme aims to investigate the technical and economical feasibility of a 600 MWe power reactor cooled by molten lead (ELSY-600). The main purpose is to demonstrate that it is possible to design a competitive and safe fast critical reactor, able to recycle its own nuclear wastes, by adopting simple engineered technical features.

The LFR features a fast-neutron spectrum and a closed fuel cycle for efficient conversion of fertile Uranium (U) and can, in principle, fission part of its wastes composed of long-lived TRansUranic (TRU) isotopes, while producing energy at an affordable cost.

Main ENEA effort in 2007 has been devoted to define a consistent reference core configuration.

Actually two options are being investigated in parallel: the first one is based on conventional wrapped hexagonal Fuel Assemblies (FAs), typical of Sodium Fast Reactor (SFR), where pins and subassemblies (S/As) are arranged in a triangular lattice. The second option consists of open square FAs, typical of Pressurized Water Reactor (PWR), where the pins and S/As are arranged in a square lattice.

The ENEA effort is being focussed on this more innovative configuration. Even if the project aims to develop a Minor Actinides (MAs) burner, in this first year the activity has been directed towards the demonstration of the ELSY potential to be fully self sustaining in Pu and to burn its own generated MAs.

The result of this “adiabatic” approach is a core design, characterised by a unitary Breeding Ratio (BR) without blankets (in order to increase the proliferation resistance goal), as well as low Pb void effect and core pressure drops (both these parameters being particularly critical in fast spectra and in lead environment).

Within the ELSY project, ENEA is responsible for the Work Package devoted to lead technology development. From this point of view, in 2007 ENEA has dedicated large effort to investigate the lead physical and chemical properties, as well as its interaction with the structural materials and the secondary coolant (water).

Also different corrosion protection coatings and corrosion resistant steels for fuel cladding, pump impellers, etc. have been studied.

Moving from a critical review of the collection of the existing data on the lead thermo-physical properties, a data base on thermo-chemical properties of Pb has been compiled.

As far as the physical effects and the possible consequences of lead/water interaction due to an anticipated steam generator tube rupture accident are considered, the programme foresees an experimental campaign to be carried out at the LiFUS V facility of ENEA-Brasimone. To this end, the facility has been modified and its instrumentation upgraded on the basis of the lesson learned from previous tests performed within the EUROTRANS project.

(II) Partitioning and Tansmutation

Activities on Partition and Transmutation, started within the 5th European Framework Program (FP), have continued within the framework of the 6th FP.

<u>ADS Transmuter</u>

ENEA is partner in the project IP EUROTRANS (EUROpean TRANSmutation) founded in the frame of the 6th Framework Programme (FP) of the European Union (EU). 51 European Organizations have the strategic R&D objective to pursue an European Transmutation Demonstration (ETD). The aim of the 4-year program, funded by the European Community, is twofold:

— Develop the conceptual design of a European Facility for Industrial Transmutation (EFIT) with a pure-lead cooled reactor of several hundreds MW with considerable Minor Actinides (MA) burning capability and electricity generation at reasonable cost. The design will be worked out to a level of detail which allows a study cost estimate

— Carry out the detailed design of the smaller XT-ADS(eXperimental Transmutation in an Accelerator Driven System (ADS)), as irradiation facility to be constructed in the short-term. The XT-ADS is also intended to be as much as possible a test facility for the main components and for operation of EFIT, at the lower working temperatures allowed by the use of the Lead-Bismuth Eutectic (LBE) as the primary coolant and spallation target material.

EFIT is being designed as a transmutation demonstrator, loaded with MA fuel. It is intended to become operational many years after the XT-ADS (around 2040) and therefore to profit of the experience gained from the running European Research an Development (R&D) programs on fuel and materials and of the operation of the XT-ADS, which is to be built and operational in the near future (about eight years from the start of the IP_EUROTRANS project).

ENEA is also partner in the EC funded project PATEROS (PArtitioning and Transmutation European Roadmap for Sustainable nuclear energy). The goal will be to establish global P&T roadmap up to the industrial scale deployment with indication of the critical milestones, preferred options and back ups, according to timescales and shared objectives at the European level.

<u>Partitioning Technology</u>

Chemical partitioning is a complex process applied to spent nuclear fuel, aimed at recovering fissile nuclides from minor actinides and fission products.

The central operation of the process is electrorefining, which takes place in an electrochemical cell, where dissolution of most fuel elements occurs, followed by a selective electrodeposition of the actinides onto a solid and/or a liquid cathode, through the application of an electrochemical difference among elements in molten LiCl-KCl salt and liquid cadmium (or bismuth) under high-purity argon atmosphere at 773 K.

The research efforts have been addressed to such a process (pyroprocess), and have been conducted in the frame of the European Project EUROPART (EUROpean Research Programme for the PARTitioning of Minor Actinides of the 6th FP), which covers the period 01/01/04 – 30/06/07. Experimental campaigns related to the electrorefining process with Pyrel II plant, which is operated at 460 °C under an Ar gas atmosphere, have been performed.

After the conclusion of the EOROPART Project, ENEA participates in the Collaborative Project ACSEPT (Actinide reCycling by SEParation and Transmutation of the 7th FP) that will provide a structured R&D framework to develop chemical separation processes compatible with fuel fabrication techniques, with a view to their future demonstration at the pilot level.

(III) Technological Development for ADS and ELSY

ENEA is strongly involved on Heavy Liquid Metal (HLM) Technologies to be used as coolant in nuclear systems. This R&D programme is supporting the development of waste burner based on ADS concept and Lead Fast Reactors in the frame of GEN IV initiative.

In this frame one important issue is the compatibility between structural materials and HLM, namely lead alloys. Indeed, irradiation experiments of structural materials in presence of lead alloys are mandatory. ENEA is preparing an irradiation programme through ISTC in order to perform experiments in BOR 60 reactor.

Lead and LBE technologies are studied mainly at the ENEA Brasimone Center utrilizing the medium and large scale facilities CHEOPE, LECOR and CIRCE; the aim is to study the structural materials behaviour, the control of corrosion/erosion phenomena and impurities treatment methods.

Moreover, an integral experiment , ICE (Integral Circulation Experiment) aimed at studying the thermal hydraulic of heavy liquid metal reactor, is in progress near the Brasimone Laboratories.

(IV) Evolutionary and Innovative Reactors

A three-year national programme (Strategic Funding devoted to the National Electric System R&D managed through a specific agreement between Ministero dello Sviluppo Economico and ENEA) focused on participation to international initiatives like INTD and Generation IV nuclear systems, is being started and has received financial support by the Ministry of Economic Development (5.5 MEuro for the first year with a comparable yearly funding foreseen for the rest of the programme).

The programme involves also the major national organizations still active in the nuclear sector, i.e. Ansaldo Nucleare, Ansaldo Camozzi, Del Fungo Giera Energia, CIRTEN (Italian Universities Consortium for Research in Nuclear Technologies) and SIET (an ENEA subsidiary).

Main goals of this programme are:

- Keep open the future nuclear energy option in the country
- Contribute to development of innovative nuclear energy generating systems able to compete in the perspective of the national energy mix re-arrangement expected to take place in the years ahead
- Contribute to development of innovative systems able to match public acceptability and economical interest
- Sustain growth of necessary competences through the participation to real-founded projects promising to be successful
- Support the activities aimed at the definition of national nuclear waste disposal strategy.

The program is organized into four main domains:

- Studies on nuclear energy at large, scenario studies, nuclear fuel cycle and proliferation, advising to the concerned National Authorities / Ministries
- INTD Reactors (especially concentrated on IRIS reactor)
- Generation IV Reactors (LFR and VHTR)
- Scientific support for the activities aimed at location, choice, designing and building of the nuclear waste national repository.

This national programme is also intended to be synergetic and coherent with the Generation IV initiative, as well as with a number of projects of the 6th an 7th Euratom Framework Programme, to which the so-called “Presidio Nucleare” (Nuclear Presidium) – set up within the Nuclear Department of ENEA – is significantly contributing to. These on-going projects are:

- ELSY – European Lead-cooled SYstem, coordinated by Ansaldo Nucleare;
- RAPHAEL - ReActor for Process heat, Hydrogen and Electricity generation;
- EISOFAR – Roadmap for a European Innovative SOdium cooled FAst Reactor.

Japan

The Japan Atomic Energy Agency (JAEA) has been proceeding with the research and development on fast reactors (FRs) and an accelerator-driven system (ADS). The participants from JAEA reported the activities in Japan covering the period from April 2007 to March 2008.

Since the issuance of the Framework for Nuclear Energy Policy in October 2005 by Atomic Energy Commission (AEC) of Japan, the significance of the development of fast reactor cycle technology has been recognized once again in the national fundamental nuclear energy policy. In March 2006, the Council for Science and Technology Policy of the cabinet office selected a fast reactor cycle technology as one of key technologies of national importance in the third-term “Science & Technology Basic Plan.” After this, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI) respectively have investigated action plans for nuclear technologies and published their reports. In response to the action plans and the review by MEXT of the result of Feasibility Study (FS) Phase-II, the AEC decided the “Basic Policy on R&D of FBR Cycle Technologies over Next Decade” on 26December 2006.

JOYO has irradiated oxide dispersion strengthened ferritic steel (ODS), and MOX fuel with 5% americium and with both neptunium and americium since the 3^{rd} duty cycle in 2006, and has completed the operation to the 6^{th} duty cycle in 2007.
With regard to MONJU, its modification work and the function test for modified systems had completed respectively in May and August 2007. Currently, the entire system function test is conducted toward the restart scheduled in October 2008. Seventy-seven of a total of 141 test items were already completed as of 9 May 2008.

Based on the Japanese policy, a Fast Reactor Cycle Technology Development (FaCT) Project was launched as an advanced stage toward commercialization of fast reactor cycle technology. The main development issues were identified as 13 issues for fast reactor and 12 issues for fuel cycle based on the results of FS phase-II study. Design study and R&D of innovative technologies are now in progress aiming at deciding adoption of innovative technologies by judgment of their applicability in 2010, and presenting the conceptual designs of commercial and demonstration facilities in 2015. International collaboration plays an important role in development of fast reactor cycle technology, as its development actually needs a long-term effort and large resources. So the development will be carried out efficiently by making the best use of multilateral and bilateral collaboration.

The ADS for the transmutation of long-lived radioactive nuclides proposed by JAEA is a lead-bismuth eutectic (LBE) cooled fast sub-critical core with 800 MWth. Various activities were conducted during the fiscal year of 2007 to investigate the feasibility of the ADS from viewpoints of the accelerator, LBE handling technology, and sub-critical core design. The design study and discussion of effective application on the Transmutation Experimental Facility (TEF) was also continued under a framework of J-PARC (Japan Proton Accelerator Research Complex) project.

Kazakhstan

General issues

According to the President’s Annual Communication, the following activities were implemented:

- The pre-feasibility study on energy policy up to 2030 prepared by the National Nuclear Center of the Republic of Kazakhstan (NNC of RK) shows that a 17-22% nuclear electricity share is optimal for Kazakhstan
- Based on this pre-feasibility study, the Ministry of Energy prepared the document titled “Main provisions of Development of Nuclear Power in the Republic of Kazakhstan up to 2030” and submitted it to the Government
- Taking into account the big territory and low density of population, as well as the small and decentralized electric grid, it was proposed to consider as basic a nuclear unit with 300-400 MW electric power

The atomic scientific-industrial complex of the Republic of Kazakhstan

The scientific and technological atomic structure in the Republic of Kazakhstan has three main components, i.e. (i) the uranium mining, production and related power industry, (ii) the research reactors and other test facilities, and (iii) BN-350 reactor decommissioning program.

The uranium mining, production and related power industry comprises

- Enterprises of uranium ores, geological prospecting, as well as a number of natural mines (using the mining and underground leaching techniques)
- Two U_3O_8 production plants located at Aktau and Stepnogorsk
- The Ulba metallurgical plant producing uranium fuel pellets for RBMK and VVER fuel assemblies
- The power plant MAEK at Aktau which is used for the production of heat, electricity and desalinated water and consists of three natural gas fired blocks and NPP with fast breeder reactor BN-350. The BN-350 reactor was commissioned in November 1972 and finally shut down in April 1999.

The nuclear research facilities comprise three different types of research reactors, and one non-reactor test facility on the territory of the former Semipalatinsk Nuclear Test Site, and one research reactor and sub critical assembly near Almaty. These facilities are used for nuclear safety and various other investigations. Specifically, Kazakhstan nuclear research facilities are

- WWR-K, a 10 MW light water reactor located near Almaty. Commissioned in 1967, WWR-K was temporarily stopped in 1988 for seismic improvement works and was restarted in 1998
- EWG-1M, a 35 MW light water heterogeneous vessel reactor having a beryllium reflector (period of continuous operation at the power 35 MW is 4 hours)
- IGR, a pulse (minimum half-width equals to 0.12 s) homogeneous uranium-graphite reactor having a graphite reflector. The maximum heat release is 5.2 GJ, with 1 GJ per pulse, and the maximum thermal neutron flux 7×10^{16} $cm^{-2}s^{-1}$
- RA, a ~0.5 MW thermal neutron high temperature gas heterogeneous reactor cooled by air, having a zirconium hydride moderator and beryllium reflector
- EAGLE a test facility used for investigations of fuel element melting processes under severe accident conditions.

The BN-350 reactor decommissioning program comprises the following activities: handling of spent nuclear fuel (SNF), sodium, liquid reactor waste (LRW), solid reactor waste (SRW), as well as the preparation of reactor plant buildings and structures for long term storage.

The main SNF handling activities consist of:

- Design of the Transport Package (TP) and the non-standard equipment (completed)
- Design of the sites for temporary storage, reloading and the storage facility (completed)
- Manufacture of the experimental TP, testing and licensing of the TP (completed).
- Construction of the loading (completed), reloading and storage sites (in progress), as well as manufacture, delivery and installation of the necessary equipment (in progress)
- Manufacture of the TPs (contracts for 60 TP fabrication were signed and manufacture has started), as well as manufacture of the equipment for TP transport (in progress)
- Transportation of BN-350 spent fuel and its arrangement for long-term storage is planned to start in 2009.

The main activities on sodium handling are listed below:
- Removal of caesium (completed)
- Reactor drilling and sodium draining (completed)
- Sodium residuals removal (in progress; the method selected for removal of sodium residuals is bi-carbonization followed by flushing with distilled water); experiments were performed at the Kazakhstan National Nuclear Center to test various regimes of sodium residuals removal.
- Sodium processing into caustic (in progress)
- Caustic processing into "geo-cement stone" (in progress)

The LRW handling activities are:
- The selective sorption method was selected based on the results of feasibility study and was also confirmed by the operation of a pilot facility
- The technical design of the LRW processing facility was developed
- An expert review of the LRW processing facility technical design was conducted
- The engineering and geological surveys for the LRW processing facility construction site and for the storage facility site of solidified RW containers was completed
- LRW processing facility construction is in progress

The activities on SRW handling are summarized below:
- During the ~25 years of BN-350 operation, approximately 6800 t of low and intermediate level waste was accumulated, of which ~85% is low level SRW currently located in the trenches of the SRW temporary storage at the MAEC site
- The existing temporary SRW storage does not meet the up-to-date Kazakhstan nuclear safety requirements and will be decommissioned
- The design of the SRW processing facility was developed

The activities in the area of preparation of the reactor plant buildings and structures for long term storage included:
- Based on the results of the Comprehensive Engineering and Radiation Survey (CERS), the work scope was identified, various contracts concluded, and building repairing works were initiated
- Surveillance and equipment maintenance activities were pursued, according to the respective technological requirements.

Republic of Korea

The role of nuclear power in electricity generation is expected to become more important in Korea in the years to come due to the country's increasing electricity demand and poor natural resources. In 2007, nuclear power plants claimed 25.9% of the total installed capacity, and generated as much as 35.4% of the total electricity demand. As of December 2007, there are 16 PWRs and 4 PHWRs in operation. According to "The Third Basic Plan for Long-term Electricity Supply and Demand," a total of ten new nuclear power units will be constructed by 2020. Four OPR1000s and two APR1400s are now under construction.

With continuous operation of nuclear power plants, spent fuel storage capacity is foreseen to be saturated and on-site spent fuel storage limit will be reached from 2016 on. Therefore decision making process for interim spent fuel storage is under way. For safe management of radioactive wastes including spent fuel, the Korean National Assembly passed the Radioactive Waste Management (RWM) law on 26 February 2008. Main provisions of the law are the establishment of a basic plan for RWM with the approval of Atomic Energy Commission, the establishment of an organization for RWM, and the establishment of RWM funds.

A draft long-term Sodium cooled Fast Reactor (SFR) development action plan has been prepared with milestones of standard design approval by 2020 and construction of a demonstration SFR by 2028. The process for the finalization of the draft action plan is on-going.

Based upon the experiences gained during the development of the conceptual designs for KALIMER, KAERI is developing key SFR technologies. There are three categories of activities under way 1) advanced concept design studies, 2) development of advanced SFR technologies necessary for its commercialization, and 3) development of basic technologies.

For advanced concept design studies, various candidate concepts and options are under consideration and the feasibility of each of these concepts is being studied. Advanced R&D activities are performed for an improvement of SFR economics and an assurance of its safety. For the development of basic technologies, main focus is on validating the computational tools and on developing sodium technologies.

Russia

Now there are 31 nuclear power units in operation in Russia, which are located on 10 sites. The total electric power capacity of all Russian NPP is equal 23.242 GW_e. Total electricity production by the NPP in Russia in 2007 was 158.281 billion kW·h (growth 2.35% in comparison with 2006), thus the NPP share is 15.6% of total electricity production - 1014.87 billion kW·h (share of the thermal power plants is 66.6%, share of the hydroelectric power plants - 17.6%). In 2007, load factor of Russian NPP was increased by 2.34% in comparison with 2006 and was equal to 77.74% (75.96% in 2006).

New strategy of development of a fuel-energy complex (FEC) of Russia up to 2020 and nuclear power of Russia for the period till 2050 is under development. The new strategy of the Russian FEC development provides for outstripping development of nuclear power, and fast reactors operating in the closed nuclear fuel cycle are considered as one of its key elements. The estimations show that achievement of outstripping growth of nuclear power requires commissioning not less than 2 power units per year.

Now there are under construction 2nd unit of Volgodonsk NPP, 4th unit of Kalinin NPP (both with VVER-1000 reactor), 5th unit of Kursk NPP with RBMK-1000 reactor, 4th power unit with the BN-800 reactor on Beloyarsk NPP site, power units with VVER-2006 reactor on the LNPP-2 and NVNPP-2 sites; a construction of demonstration small size nuclear power plant on the basis of a floating power unit with reactor facilities KLT-40S is scheduled in Severodvinsk in Arkhangelsk region. Simultaneously with construction of the new power units, work on extension of NPP design lifetime is carried out for units being in operation. To the present time lifetimes were prolonged for 11 power units related to the 1st NPP generation. It is supposed to extend design lifetime of operating power units by 10-15 years.

In Russia, there are 2 fast reactors in operation:
- experimental reactor BOR-60 (RIAR, Dimitrovgrad);
- commercial power unit No. 3 of Beloyarsk NPP with sodium cooled fast reactor BN-600 (Zarechny).

Research reactor BR-10 (IPPE, Obninsk) is on the stage of preparation for its decommissioning. No. 4 power unit of Beloyarsk NPP with sodium cooled fast reactor BN-800 is under construction.

NPP with the BN-600 reactor is in operation more than 28 years (as of 31.12.2007, the BN-600 reactor had been in operation on power levels more than 192 000 hours). BN-600 is the largest in the world operating power unit with fast reactor. It demonstrates high parameters of safety and operating reliability. In 2007, the NPP load factor was equal to 77.78% and average load factor for the period of commercial operation of the power unit (1982-2007), excluding initial stage of power mastering, is equal to 73.68%. Design lifetime of the BN-600 reactor plant expires in April 2010. Now activities on preparation of BN-600 lifetime extension by 15 years is carried out.

Experimental BOR-60 reactor is in operation more than 38 years. It is used for material tests, isotopes production, tests of the various equipments of fast reactors, and also for heat and electricity production. Operation of BOR-60 reactor is permitted till 31 December 2009. Now activities on its lifetime extension is implemented.

Research reactor BR-10 was finally shut down in 2002 after operation during about 44 years. Now BR-10 is on the preparatory stage of its decommissioning and it is a base for development of various technological processes proposed to be used at the SFR decommissioning.

Construction of the 4th power unit with the BN-800 reactor on Beloyarsk NPP site is carried out in accordance with the Program of Development of Nuclear Power in the Russian Federation for 2000-2005 Period and up to 2010. Date of construction completion and power unit commissioning is planned in 2012. Construction of the foundation plates of reactor compartment and turbine hall of the main building had been completed in 2007. Manufacture of the main equipment, in particular, components of the main and guard reactor vessels etc. and its delivery to site is carried out.

Now the following researches in the fast reactor area are carried out in Russia:
- Justification of lifetime extension for the BN-600 and BOR-60 reactors;
- Upgrading separate materials of the detailed design of BN-800 reactor, development of the pilot plant design for manufacture of MOX-fuel for BN-800;

- Development of advanced sodium cooled fast reactors:
  a) continuation of R&D work on development of the conceptual design of large-size commercial fast reactor with sodium coolant BN-K;
  b) continuation of conceptual development of small-size modular-transportable two-circuit NPP with sodium cooled fast reactor and gas turbine (concept of the BN GT nuclear co-generation power plant);
- Researches on fast reactors with heavy liquid metal coolant:
  a) development of basic design of SVBR-100 reactor facility with lead-bismuth coolant and organization of works on construction of SVBR-100 prototype on the IPPE site;
  b) R&D on justification of design of NPP with lead cooled BREST-OD-300 reactor, discussion of prospect of construction of a research fast reactor with lead coolant (BIRS);
- Conceptual researches on gas-cooled fast reactors;
- Joining the GIF program.

Switzerland

This report was prepared for the Laboratory for Reactor Physics and Systems Behaviour (LRS) Scientific Advisory Committee and summarizes the FAST project (**F**ast-spectrum **A**dvanced **S**ystems for power production and resource managemen**t**) activities in the area of fast reactors in 2007.

The FAST project is an PSI/NES/LRS activity in the area of static and transient analysis of fast reactor systems in different aspects, including neutronics, thermal hydraulics and structural mechanics.

One of the main priorities of the project is to keep development and improvement of a calculational tool for simulating static and dynamic behaviour of the core and the whole reactor system of advanced fast spectrum concepts with different system configurations, core designs, fuel forms, coolant types, etc. A code system of this complexity is particularly attractive in the context of core and safety-related studies of the advanced fast reactors being proposed by the Generation IV International Forum (GIF). Using this code system, it is possible to analyse in a systematic manner a wide variety of both equilibrium conditions and transients. In addition, through the modelling of the whole reactor system, it is possible to assess those phenomena, which depend on the direct interaction between the primary and secondary systems and the core behaviour. This code system allows for comparing different aspects of the GIF systems, e.g. efficiency of burning minor actinides, behaviour in accident conditions, etc. One of the important developments of the FAST code system made in 2007 was the elaboration of the 3D equilibrium fuel cycle procedure (see "Equilibrium cycle calculational procedure for fast reactors" by S. Pelloni, J. Krepel and K. Mikityuk).

In order to provide a framework for the FAST project it is necessary to participate in international collaborations and during 2007 the FAST project was fully integrated into the Generation IV Gas Fast Reactor (GFR) project both through a Swiss national contribution and as part of the EU Gas Cooled Fast Reactor 6th Framework Program (FWP) — GCFR. Currently prior to the formalising of the Gen IV GFR project the national contribution is being performed in collaboration with the CEA through a CEA/PSI GFR bilateral agreement. In addition, the FAST project represents PSI on the GFR design and safety project management board and the GFR steering committee. The negotiation is under way on participation of the FAST project in the 7th FWP EU Gas Cooled Fast Reactor Project. The examples of the work performed in 2007 on gas cooled fast systems are provided in the following publications: “GFR equilibrium fuel cycle analysis” by J. Krepel, S. Pelloni and K. Mikityuk; “Development and benchmarking of the 3D TRACE/PARCS model of the GFR core for transient analysis” by G. Girardin, P. Coddington, K. Mikityuk and R. Chawla; “Benchmarking of a thermal-mechanical part of the GFR fuel model” by P. Petkevich, K. Mikityuk, P. Coddington and R. Chawla; “Comparative transient analysis of the 2400 MWth GFR with the TRACE and CATHARE codes” by A. Epiney, P. Dumaz, P. Coddington, K. Mikityuk and R. Chawla; and “Transient analysis in ETDR” by D. Blanchet and P. Coddington. In particular, “GFR equilibrium fuel cycle analysis” presents the GFR equilibrium fuel cycle analysis performed within the framework of the post-Doc study started at the beginning of January 2007 on the comparative analysis of minor actinide burning capability within Gas, Sodium and Lead cooled fast reactor systems.

In addition to the studies on gas cooled fast reactors work has continued on liquid metal systems. The project will in 2008 provide contributions to the EU ELSY project in the areas of core thermal-hydraulics and the neutronic analysis of minor actinide burning. In frames of this project a comprehensive study of available test data and models for heat transfer to the liquid metal flowing in the tube bundles was performed in 2007 and a new correlation for heat exchange coefficient was proposed (see “Heat transfer to liquid metal: review of data and correlations for tube bundles” by K. Mikityuk). The expertise gained within the FAST project in analysing heavy liquid metal systems has lead to the project providing support to the PSI MEGAPIE project. In particular the reference accident for the MEGAPIE target was analysed with the FAST code system (see “Analysis of radioactivity releases in the MEGAPIE reference accident” by K. Mikityuk, P. Coddington and F. Gröschel). As a sodium-cooled fast reactor is considered a new important priority for the FAST project, the new bilateral cooperation with CEA in the area of the Generation IV Sodium Fast Reactor was initiated in 2007 and contribution of the FAST project to the 7th FWP EU Sodium Cooled Fast Reactor Project is under negotiation.

The very important cross-cutting aspect of the FAST code system development is integration in the system of an uncertainty assessment methodology which allows to make static and transient best-estimate analysis with account for uncertainties in the input parameters, material properties and methodical errors (see “An uncertainty assessment methodology for the FAST code system” by D. Blanchet, K. Mikityuk, P. Coddington and R. Chawla).

An important feature of the FAST project is that it provides a good vehicle for student projects and during 2007 the project has supported three PhD students on different aspects of GFR analysis (see “Development and benchmarking of the 3D TRACE/PARCS model of the GFR core for transient analysis”; “Benchmarking of a thermal-mechanical part of the GFR fuel model”; and “Comparative transient analysis of the 2400 MWth GFR with the TRACE and CATHARE codes”), while the fourth PhD student started her study in October 2007 on modeling single- and two-phase sodium flow. One of the key features of the FAST project is the ability to offer PhD students an attachment to CEA/Cadarache to work on different aspects of the GFR design and safety analysis. In this respect during 2007 a student was attached to the CEA Cadarache to work on the GFR safety analysis and design of alternative Decay Heat Removal systems (see “Comparative transient analysis of the 2400 MWth GFR with the TRACE and CATHARE codes”). The attachment of the new PhD student to CEA to work on the two-phase sodium flow simulation is also currently discussed.

USA

The U.S. status report summarized the new U.S. led initiative: Global Nuclear Energy Partnership (GNEP) and a status report on Innovative Technology Options (Advanced Materials and Advanced Energy Conversion), Lead Cooled Fast Reactor research, Reactor Simulation activities, and Advanced Fuels Program in the U.S. In particular the role of fast reactors for a closed fuel cycle was discussed and a summary of the initial advanced concept studies was presented.

To expand nuclear power to help meet growing energy demand in an environmentally sustainable manner, the DOE NP2010 program is being pursued to facilitate the deployment of advanced light water reactors (ALWRs). In conjunction, the Global Nuclear Energy Partnership (GNEP) is targeted to develop, demonstrate, and deploy advanced technology for recycling spent nuclear fuel that provides key waste management and proliferation (no separation of plutonium) benefits. The development of fast reactor technology is a major component of this fuel cycle strategy. In addition, the Generation-IV program continues advanced reactor research and development with particular focus on the very high temperature gas reactor (VHTR) and sodium cooled fast reactor (SFR) technologies.

The GNEP fuel cycle strategy is based on sustained (and expanded) nuclear power production in ALWRs. The spent fuel is separated into several components for tailored waste management. The transuranics are recycled to advanced recycle reactors where they are consumed for further power production. Fast spectrum reactors are utilized for closed recycle and "burning" of these materials. The development of recycle fuels and management of the waste products from the ALWR and fast reactor recycle are other important technology missions. The overall strategy is focused on waste management and non-proliferation benefits.

The current GNEP approach is to quickly (~2020 time frame) develop industry-led prototype facilities for the fast reactor and LWR spent fuel separation. These facilities will demonstrate the key technology and fuel cycle benefits. Concurrently, a DOE laboratory-led technology development and research program will continue. This work will focus on innovative fuel cycle technologies including recycle fuel development. For the fast reactor research, the critical focus will be on capital cost improvements. Three avenues are being pursued for cost reduction: design simplifications, new technology, and advanced simulation.

The status report gave a brief summary of the following U.S. GNEP activities: priority nuclear data measurements, advanced structural material (austenitic and ferritic alloys) development, sodium loop plugging test activities, small scale supercritical CO_2 Brayton compressor testing, and a safety benchmarking compilation and analysis activities.

Next, the status report gave a brief summary of the lead cooled fast reactor analysis activities conducted at ANL.

The GNEP simulation and modeling activities is discussed. Examples of the neutronic, thermal fluid dynamics, and structural modeling activities are presented. Specifically, the adaptive neutron flux solution options and the multi-resolution thermal fluid dynamics approach were highlighted.

Finally the status report concluded with a summary of the INL lead GNEP nuclear fuels program. The integration of the modeling and simulation, integral experimental, and R&D infrastructure activities was stressed. The experimental activities were briefly discussed. A summary of the experimental irradiation of metal and oxide SFR fuels at ATR and the testing in the FUTURIX-FTA Irradiation in the Phénix Reactor (matching compositions in ATR AFC Test Series) was presented.

The conclusions from this status report are:

- Development of advanced technologies for cost reduction and safety are being developed through five R&D areas: nuclear data, advanced materials, engineering research, advanced energy conversion, and safety technology
- Near-term technology development needs will be specified by the Advanced Burner Reactor (ABR) Project (potential for international facility sharing)
- The technology development is closely integrated with Reactor Simulation
- International R&D collaborations are being pursued by the U.S. through trilateral, Generation-IV, and bilateral arrangements.

3. Review of Activities; Conclusions and Actions

The meeting reviewed national and international research and technology development activities in the area of fast neutron systems (critical and sub-critical). The meeting was informed about three INPRO collaborative projects in the area of fast reactors (viz. COOL, GAINS, and “Integrated Approach on DHRS for LMRs”, see presentations in the attachments), and discussed synergies with these activities. The meeting further reviewed the status of the activities performed within the framework of the TWG-FR, and discussed possible future activities within the framework of IAEA’s Programme and Budget cycle 2008 – 2009, and beyond.

The main conclusions and actions are summarized below:

(i) Clarification about Russian contribution still needed to complete the report on “Updated Codes and Methods to Reduce the Calculational Uncertainties of the LMFR Reactivity Effects” (deadline: end of July 2008)

(ii) Report “Studies of Innovative Reactor Technology Options for Effective Incineration of Radioactive Waste” will be published before end of 2008

(iii) China joins the CRP on “Analyses and Lessons Learned from the Operational Experience with Fast Reactor Equipments and Systems”. For US participation, TWG-FR Scientific Secretary has to contact INL (before end of June)

(iv) Contract and research agreement proposals to be provided within 2 weeks (15 June 2008) for the “MONJU” (India and China, maybe Switzerland) and “PHENIX” (France, India and China, Germany, maybe Switzerland) CRPs

(v) With regard to the Indian CRP proposal “Optimum Plant Parameters with Metallic and MOX Fuelled FBRs”, briefly presented by the IGCAR representative, agreement was reached within the TWG-FR that the proposal is basically a benchmark of structural analysis and design codes. Before they could consider their participation, the TWG-FR members are requesting the following further clarifications from the Indian colleagues (deadline: end of June 2008): (i) precise the scope and the objectives, and (ii) fully specify the benchmark cases to be treated and the corresponding input data. The next step would consist in a consultants’ meeting convened by the TWG-FR Scientific Secretary to precise the tasks of the CRP. Provided the requested clarification arrive end of June, the deadline for the TWG-FR members to notify their expression of interest is end of July 2008.

(vi) With regard to the Indian CRP proposal “Estimation of source term for radioactivity release after CDA”, briefly presented by the IGCAR representative, agreement was reached within the TWG-FR that the objective of the CRP was not to perform a whole CDA assessment, but rather to investigate the relevance of radioactive products behaviour in the sodium, the cover gas, as well as their transport to the reactor containment building. Before they could consider their participation, the TWG-FR members are requesting the following further clarifications from the Indian colleagues: (i) precise the scope and the objectives, and (ii) fully specify the benchmark cases to be treated and the corresponding input data. The next step would consist in a consultants’ meeting convened by the TWG-FR Scientific Secretary to precise the tasks of the CRP. Provided the requested clarification arrive end of June, the deadline for the TWG-FR members to notify their expression of interest is end of July 2008.

(vii) The TWG-FR discussed a proposal to produce a catalogue on unexpected reactivity events and the respective investigation in various fast reactors. It was decided to consider this action within the CRP “Analyses and Lessons Learned from the Operational Experience with Fast Reactor Equipments and Systems”.

(viii) With regard to the implementation of the TWG-FR’s extra-budgetary activity on “NE Societal Aspects/FR Acceptance”, names of contact persons to join the task group in charge of producing are still needed for Germany, Russia and the US (deadline for nominating the experts: end of June 2008).

(ix) The TWG-FR confirmed the planned topical Technical Meetings for 2008, i.e. “Design features of advanced sodium cooled fast reactors with emphasis on economics” to be held in Vienna and “Fuel handling systems of sodium cooled fast reactors” to be hosted by IGCAR in Kalpakkam. For both Technical Meetings, a first draft of the program will be prepared and distributed to all TWG-FR members by the Russian colleagues and the Indian colleagues, respectively (deadline: June 2008). All TWG-FR members are requested to send (deadline: July 16 2008) their comments, proposals for the topical contents, and the name of contact persons to the TWG-FR Scientific Secretary.

(x) The TWG-FR discussed the list of topical Technical Meetings for 2009 and beyond, and provisionally reached the following agreement:

- “Seismic design” to be convened in 2009 and coordinated by Italy; action was put on the Italian TWG-FR representative to submit to the TWG-FR Scientific Secretary a proposal outlining scope, topics and technical content of the meeting (deadline: end of June 2008)
- “Innovative Steam Generators” to be convened in 2009; action was put on all Member States representatives to inquire about the possibility to take the lead (deadline: end of July 2008)
- “Status and innovative solutions for ISIR” to be convened in 2010; action was put on all Member States representatives to inquire about the possibility to take the lead (deadline: end of July 2008)
- “Innovative fast reactor designs with enhanced negative reactivity feedbacks” to be convened in 2010; action was put on the representative from Germany to inquire about the possibility to take the lead

— It was decided to drop two previously submitted proposals (viz., the topical Technical Meetings on “Mitigation of gas entrainments” and on “Design criteria for issues not covered in current design codes”).

(xi) The TWG-FR discussed possible subjects for workshops/symposia/seminars after 2009. The following proposals were put forward:
- Workshop on “Science and technology of sodium fires”
- Seminar on “Lessons learned from MONJU restart”, including lectures on the status of fast reactors and their experimental capabilities
- Workshop on Advanced core and structural materials for future fast reactors”
- Seminar on “Fast reactor decommissioning experiences and guidelines for future reactor design

Provided funding levels are sufficient and interest of the TWG-FR members is maintained, the TWG-FR Scientific Secretary will propose implementation of one or more of these information exchange activities.

(xii) The TWG-FR members expressed interest for information exchange on the PHENIX EOL tests. It has been agreed to plan a specific information exchange session in conjunction with one of the Research Coordination Meetings (RCMs) of the corresponding CRP on “Control Rod Withdrawal and Sodium Natural Circulation Tests Performed during the PHENIX End-of-Life Experiments”.

(xiii) The TWG-FR members expressed interest for information exchange regarding the outcome of the INPRO joint study on “Closed Nuclear Fuel Cycle with Fast Reactors (CNFC-FR)”. Action (deadline 16 June 2008) to contact the CNFC-FR responsible (V. Usanov).

(xiv) TWG-FR members agreed that fast Spectrum molten salt reactor concepts are included in the scope of the TWG-FR. It has been decided to include these concepts in the Fast Reactor Status Report” currently under preparation.

(xv) The TWG-FR members decided to maintain the deadline of publishing the two Status Reprts (on Fast Reactors and ADS, respectively) before the end of 2008.

(xvi) Specific actions were identified for the Fast Reactor Status Report:

a. Chapter Leads and Section Leads need to send (deadline: 16 June 2008) a detailed report summarizing the status of their chapters and sections to A. Stanculescu/G. Imel (gimel@isu.edu, phone 208 282-3732)/E. Fujita
b. All Country Leads to inform (deadline: 16 June 2008) A. Stanculescu/E. G. Imel/E. Fujita via email of any changes to the responsibilities in the spreadsheet summarizing responsibilities for contributions (a positive or negative response is requested, do not update the spreadsheet, inform by email message)
c. For France, J. Rouault, will update the spreadsheet (deadline: 16 June 2008) and send to A. Stanculescu/G. Imel/E. Fujita
d. All contributors to resend their material to J. Rouault (deadline: 16 June 2008) for all chapters and sections where France has assumed the lead
e. E. Fujita to distribute the updated spreadsheet to the TWG-FR members (deadline: 30 June 2008)
f. TWG-FR members to forward the updated spreadsheet to their respective national contributors (deadline: 7 July 2008)

g. All Chapter Leads and Section Leads to contact contributors who have not provided input (please be aggressive!)
h. If no input was provided by the contributors, the Chapter and Section Leads to use material from previous Status Report
i. A. Stanculescu/G. Imel/E. Fujita to issue new schedule (deadline: 31 July 2008)
j. IAEA to establish FTP website and inform all participants (deadline: 31 July 2008)

(xvii) A similar list of actions was agreed upon also for the ADS Status Report:

a. Chapter Leads to send (deadline: 16 June 2008) a detailed report summarizing the status of their chapters and the current compiled chapters (if any) to A. Stanculescu/D. De Bruyn
b. Chapter Leads to follow on and inform A. Stanculescu/D. De Bruyn about the specific actions that are ongoing for the missing contribution
c. Chapter Leads to send (deadline: 31 July 2008) the revised version of their chapters to A. Stanculescu/D. De Bruyn
d. IAEA to establish FTP website and inform all Chapter Leads (deadline: 31 July 2008)

(xviii) The TWG-FR members recommend publishing a small brochure for public information on the merits of the fast reactors and closed fuel cycle. The TWG-FR members recommend that this task be implemented within the framework of the "societal aspects and public acceptance of fast reactors" activity (extra-budgetary activity supported by the Japanese government)

(xix) The Indian TWG-FR representative proposed to produce as NE document a publication on the "Current Status and Future Trends on Electrochemical Sensors for Liquid Metal Fast Reactors". The TWG-FR Scientific Secretary will submit the proposal to the IAEA for consideration.

(xx) Next TWG-FR meeting is planned for the week of 25 May 2009. Members are asked to submit proposals for hosting the 42^{nd} meeting by end of September 2008. The default venue is IAEA Headquarters if no proposals are submitted.

The TWG-FR members express their gratitude to the IAEA hosts for the warm welcome and hospitality.