Overview of EU Research Activities in Partitioning and Transmutation and Innovative Reactor Systems within the EURATOM Framework Programmes

V. P. Bhatnagar

European Commission, BE-1049 Brussels

Email contact: Ved.Bhatnagar@ec.europa.eu

Abstract. European Union's (EU) (currently 27 Member States) shared-cost research has been organised in Framework Programmes (FP) of durations of 4-5 years since 1984. The 6th European Atomic Energy Community (EURATOM) Framework Programme (2002-06) and the current 7th FP (2007-11) have been allocated a fission research budget respectively of 209 and 287 Million Euro from the European Community (EC). In FP6, there are 11 projects (total budget 82 M€, EC contribution 44 M€) in all aspects of partitioning and transmutation (P&T) ranging from road-mapping exercise to large integrated projects on chemical separation, accelerator driven systems, lead-cooled Fast critical systems for waste transmutation, technology, fuel, accelerator facilities for nuclear data etc. In Innovative Reactor concepts, there are about half-a-dozen projects (total budget 30 M€, EC contribution 14 M€) including High Temperature Reactors, Gas-cooled Fast reactors, road-mapping exercise on sodium fast reactors etc. The main research and training activities in FP7 are: management of radioactive waste, reactor systems, radiation protection, infrastructures, human resources and mobility and training. In the two call for proposals (2007 and 2008) in FP7, 10 projects have been accepted in P&T and Innovative Reactor concepts (total budget 92 M€, EC contribution 44 M€). These research projects cover activities ranging from chemical separation, materials, fuels, treatment of irradiated graphite waste and European sodium fast reactor to the establishment of a Central Design Team of a Fast-spectrum Transmutation Device in Europe. The third call for proposals is underway requesting proposals on nuclear data, thermal hydraulics, gas and lead-cooled fast reactor systems with a total EC budget of 20 M€. International collaboration is an important element of the EU research policy. This overview paper presents elements of the strategy of EURATOM research and training in waste management including accelerator driven transmutation systems and Innovative Reactor concepts that are being pursued through Euratom Programmes. A brief outline of FP6/FP7 research projects is also outlined.

1. Introduction

Promotion of collaborative research and training in nuclear energy in Member States of the European Union (EU) has been at the heart of the EURATOM Treaty (1957) and since its inception, it has acted as a driving force for the development of nuclear power in the EU. For the long-term sustainable economic growth, the objective of the energy research in the EU is to transform the current fossil-fuel based energy system into a more sustainable one based on a diverse portfolio of energy sources and carriers combined with enhanced energy efficiency, to address the pressing challenges of security of supply and climate change, whilst increasing the competitiveness of Europe's energy industry.

European Community research has been organised in Framework Programmes (FP) of durations of 4-5 years since 1984. In this regard, one of the objectives of EU is to achieve greater co-operation between Member States' research strategies and a mutual opening up of programmes. With the challenges and prospects opened up by the technologies of the future, there is a need that European research efforts and capacities should be more thoroughly integrated. With this view in mind, the European Commission launched the so-called 'European Research Area' (ERA) initiative in January 2000 [1]. Framework Programmes research activities are geared to make ERA a reality.

Priorities for the European Union's research and development activities for the Sixth Euratom Framework Program (FP6) [2] dealt with a number of research areas combining technological, industrial, economic and social aspects (see section 2). However, the current FP7 (2007-2011) [3] focuses on research areas such as nuclear waste management including geological disposal and P&T, safety of existing reactor systems and advanced Gen IV reactor concepts, radiation protection, support for research infrastructures and retaining competences and know-how in all areas of nuclear science.

The European Technology Platform on Sustainable Nuclear Energy (SNE-TP) [4] has been launched on 21 September 2007. A strategic research agenda (SRA) has been developed by the members of SNE-TP. The topics foreseen in the SRA and their priorities form an input to the yearly Euratom work programme making calls for proposals.

2. The EURATOM Sixth Framework Programme (FP6) (2002-2006)

The scientific and technical goal of the Euratom FP6 Specific Program "Research and Training Program on Nuclear Energy" has been to help exploit the full potential of nuclear energy, both in the long and short term. Its development and exploitation is to be done in a sustainable manner while combating the climate change and reducing the energy dependency of the EU. Nuclear fission research and development activities in this programme have been subdivided into (a) Management of radioactive waste, (b) Radiation protection and (c) Other activities in the field of nuclear technologies and safety.

In the area (a), the priority has been to find a permanent and safe solution for the management of long-lived, high-level waste that is acceptable to society. This includes establishing a sound technical basis for the demonstration of long lived high level waste disposal in geological formations. This is to be supported by studies on P&T and further supplemented by exploring the potential of system concepts that would by themselves produce less waste in nuclear energy generation. Combating the decline in both student numbers and teaching establishments by a better integration of European education and training in nuclear safety and radiation protection is another important aim. Description of area (b) is out of scope of this paper.

In the area (c), the activities are intended to respond to the scientific and technical needs of the policies of the European Community in the fields of health, energy and the environment. The aim is to ensure that the European capability is maintained at a high level in relevant fields not covered by the areas (a) and to contribute towards the creation of the European Research Area. These activities are carried out mainly in the following areas: (i) innovative concepts: evaluation of the potential of innovative concepts that offer advantages in terms of safety, environmental impact, resource utilisation, proliferation resistance, development of improved and safer processes in the field of nuclear energy, (ii) education and training concerning nuclear safety and radiation protection aimed at integration and consolidation of national efforts to achieve economy of scale, and covering in addition such areas as mobility and human resources, trans-national access to infrastructure, and coordination activities, and (iii) measures for the safety of existing nuclear installations.

In FP6, research in P&T includes areas such as fundamental assessment of the system and safety aspects of the overall concept of P&T and, in particular, of its impact on waste

management and geological disposal. In the area of partitioning, continued R&D of hydrometallurgical and pyro-chemical processes was implemented with a view to a demonstration of the most promising techniques. In the area of transmutation, the development of basic knowledge and technologies for transmutation and evaluation of their industrial practicability, in particular, of transmutation devices such as accelerator driven sub-critical systems (ADS) is proposed.

In FP6, research aims in advanced reactor systems are compatible with those of Gen IV International Forum for the development of Gen IV reactors, namely (i) sustainability (enhanced fuel utilisation and optimal waste management), (ii) economics, (iii) safety and reliability and (iv) proliferation resistance and physical protection. In FP6, the following Advanced Reactor systems are being investigated: Very High Temperature Reactor (VHTR), Gas Cooled Fast Reactor (GFR), Supercritical Water Reactor (SCWR), Lead Cooled Fast Reactor (LFR), Sodium Cooled Fast Reactor (SFR) and Molten Salt Reactor (MSR).

Three Calls for proposals including topics in P&T have been made in December 2002 and November 2003 and June 2005 respectively. In the first two calls, the so-called new instruments (such as Integrated Projects) were used as a priority. The Integrated Projects (IPs) are designed to give increased impetus to the European Community's competitiveness and/or to address major societal needs by mobilising a critical mass of research and technological development resources and competencies. In the third call, in addition, the Integrated Infrastructure Initiatives (III) instrument was also used to establish a durable networking of research infrastructures across EU such as Heavy Liquid Metal (Lead and Lead-Bismuth) loops or accelerators for nuclear data applications. Specific Targeted Research Projects (STREP) are sharply focused on research and technological development designed to gain new knowledge either to improve or develop new products, processes or services or to meet other needs of society and Community policies. Coordination Actions (CA) are used for coordination or networking activities of consortia across EU without carrying out new research and development. Avoiding the micro management, increased autonomy has been given to consortia in the management (both scientific and financial) of projects that are judged on the global end-results.

2.1 The Research Activities on P&T in FP6

The projects in the area of P&T that were selected for funding in Euratom FP6 are given in Table 1. The reader is referred to each project's respective website for details of the objectives and results achieved and current status (see Table 1). **PATEROS** project is a 2-year Coordination Action establishing a global P&T roadmap leading up to the industrial scale deployment of necessary facilities. A common objective of all strategies using P&T is to reduce the burden on a long-term waste management, in terms of radio-toxicity, volume and heat load of high-level nuclear waste which has to be disposed of in final repositories. Possible strategies can range from using dedicated transmuters in a separate fuel cycle stratum in a stable or expanding nuclear energy scenario in order to reduce drastically the amount of nuclear waste to be sent to the repository, down to the scenario of a nuclear phase-out. **RED-IMPACT** is a 3-year project studying the impact of P&T, conditioning and waste reduction technologies on reducing the burden associated with radioactive waste management and disposal. P&T is likely to ease the final repository requirements and it will also contribute to the sustainability of nuclear energy in those countries that pursue this source of energy. **EUROPART** is a 3-year project studying the

Table 1: Euratom FP6 P&T projects underway indicating their salient features

	Acronym	Abbreviated Title	Budget (M€)		Co-ordinator	Start date & duration
			Total	EC		
1	PATEROS	P&T European Road-map http://www.sckcen.be/pateros/	0.8	0.6	SCK/CEN (BE)	01/09/2006 24 months
2	RED-IMPACT	Impact study of P&T on Waste management http://www.red-impact.proj.kth.se/	3.9	2.0	KTH (SE)	01/03/2004 36 months
3	EURO PART	Partitioning techniques and processes http://www.europart-project.org/	11.2	6.0	CEA (FR)	01/01/2004 42 months
4	EURO TRANS	All Aspects of Transmutation by sub-critical ADS http://nuklear-server.ka.fzk.de/eurotrans/	45.0	23.0	FZK (DE)	01/04/2005 60 months
5	ELSY	Waste transmutation in Lead Cooled critical system http://www.elsy-lead.com/	6.9	2.95	ANSALDO (IT)	01/09/2006 36 months
6	PUMA	Pu and MA Management by thermal Gas-cooled system http://www.puma-project.eu/	3.7	1.85	NRG (NL)	01/09/2006 36 months
7	VELLA	Networking of lead loop infrastructures in Europe http://www.3i-vella.eu	3.3	2.3	ENEA (IT)	01/10/2006 36 months
8	LWR-DEPUTY	LWR fuels for deep burning of Pu in thermal systems http://www.sckcen.be/lwrdeputy/	2.4	1.25	SCK/CEN (BE)	01/08/2006 48 months
9	EFNU DAT	Networking of EU facilities for nuclear data measurements http://nuclear-astrophysics.fzk.de/efnudat/	3.0	2.4	CNRS (FR)	01/11/2006 48 months
10	CAN-DIDE	Networking of Nuclear data for EU Industrial Development http://candide.nri.cz/	0.8	0.8	UU (SE)	01/01/2007 24 months
11	NUDAME	Trans-national access for nuclear data measurements http://www.irmm.jrc.be/	0.2	0.2	EC-JRC (IRMM)	01/04/2005 36 months
		Totals	**81.2**	**43.35**		

development of methods for the separation of individual minor actinides that are contained in aqueous nuclear wastes issuing from the reprocessing of uranium oxide (UOX) or mixed oxide (MOX) nuclear spent fuel. It also studies separation of grouped actinides (An) for recycling. Partitioning techniques used are: (i) hydrometallurgy and (ii) pyro-metallurgy. The flow-sheet of various processes including the conditioning methods for the wastes to be generated by the partitioning processes are also established. Processes for possible industrialisation of partitioning strategies have also been looked at.

EUROTRANS is a 5-year project carrying out a preliminary detailed design of a ≈100 MW experimental facility demonstrating the technical feasibility of transmutation in an accelerator driven System (XT-ADS) in a short term as well as to accomplish a reference conceptual design (several 100 MW) of a modular generic European Transmutation Demonstrator (ETD) in a long-term. Also a zero-power lead fast critical facility connected to a continuous beam neutron generator is also being operated to allow a validation of the on-line sub-criticality monitoring, the validation of neutronic calculation codes to reduce design safety margins and to support licensing applications for the construction of an experimental device. It also carries out studies on fuels, materials and neutron data for relevant isotopes. **ELSY** is a 3-year project studying lead cooled fast critical systems with a view to demonstrating that it is possible to design a competitive and safe system using simple engineered technical features. Safe burning of recycled minor actinides in the core of ELSY will also be studied. **PUMA** is a 3-year project dealing with important issues concerning the use of Pu and MA in gas-cooled reactors and to provide additional key elements for the utilisation and transmutation of Pu and MA in current and future (high temperature) gas-cooled reactor designs, contributing to the reduction of Pu and MA stockpiles, and to the development of safe and sustainable reactors. **VELLA** is a 3-year Integrated Infrastructure Initiative project. It aims to create a virtual European laboratory for 'Lead Technologies'. Its final goal is the creation of a network of the EU laboratories that operate devices using heavy liquid metals technologies, especially lead alloys. **LWR-Deputy** is 4-year project conceived to fit into a portfolio of experimental research projects on novel fuels for deep burning of plutonium in existing nuclear power plants (NPPs). It will investigate to what extent the existing NPPs in Europe can create markedly less nuclear waste by moving to inert matrix fuels.

EFNUDAT is a 4-year project planning to integrate all infrastructure-related aspects of nuclear data measurements by organising networking activities to optimise the use of the facilities for nuclear data measurements and the analysis and dissemination of results, Transnational Access Activities procuring approximately 4000 additional beam hours for external users that will carry out nuclear data measurements, and Joint Research Activities to raise the performance of the facilities and the efficiency of their use. **CANDIDE** is a 2-year coordination action to establish a durable networking of nuclear data efforts that are important in the context of minimising the high-level waste stream of nuclear energy. The purpose is to identify the needs for improved nuclear data, assess the present status of knowledge, and to estimate what accuracy can be reached with state-of-the-art techniques for the relevant fast critical reactors and sub-critical ADS. **NUDAME** is 3-year project aiming to promote trans-national access to facilities at IRMM-JRC, Geel for neutron data measurements.

2.2 The Research Activities on Advanced Reactor Systems in FP6

The projects in the area of Advanced Reactor Systems that were selected for funding in Euratom FP6 are given in Table 2. The reader is referred to each project's respective website for details of the objectives and results achieved and current status (see Table 2)

RAPHAEL (Reactor for Process Heat, Hydrogen and Electricity Generation) is focused on the main technology developments needed for VHTR industrial deployment. It explores the performance of the individual system elements in challenging conditions of temperatures up to 1000 °C and burn-ups greater than 150 GWd/tHM and integrates the results in order to assess the viability of the whole system. The research involves exploring

the limits of performance of the fuel and materials and developing innovative technologies for system components. It also explores potential interfaces with hydrogen production or process heat exploitation, describing an acceptable nuclear safety approach.

The Gas-Cooled Fast Reactor (**GCFR**) project explores the advantages of a high-temperature, gas-cooled fast reactor primarily used as an electricity generator, which also has the potential to support hydrogen production. The project identifies promising concepts for innovative refractory fuel with enhanced fission product retention and the potential for full actinide recycling, possibly via an integrated on-site fuel-reprocessing unit. The key milestones concern the safety approach, the pre-selection of design options and the preliminary viability of GCFR. Parallel activities are on-going for the Experimental Technology Demonstration Reactor (ETDR), which could start operation in 2020 to qualify key technologies.

The High-performance Light-water Reactor Phase 2 (**HPLWR Phase 2**) project assesses the main scientific issues and the technical feasibility of supercritical water concept. As for coal-fired power plants, cost reductions are envisaged for reactors using supercritical water as coolant due to size reduction of key components and higher plant efficiencies. In HPLWR, the supercritical coolant pressure is around 25 MPa and its temperature varies from 280 °C to more than 500 °C. Its net thermal efficiency of 44 % is far greater than for conventional light-water reactors. Most of the study is devoted to the thermal neutron option, but the fast neutron option will also be investigated. Safety systems will be assessed for compatibility with the current European Utility Requirements.

The Sodium Cooled Fast Reactor (SFR) and Molten Salt Reactor (MSR) are addressed in two smaller projects. **EISOFAR**, has the main objective of preparing a preliminary roadmap for a European Sodium Cooled Fast Reactor (ESFR). **ALISIA**, has the aim of strengthening the existing European network of expertise in this area.

Table 2: Euratom FP6 Advanced Reactor projects underway

	Acronym	Project Title	Budget (M€)		Co-ordinator	Start date End Date
			Tot	EC		
1	RAPHAEL	Reactor for Process Heat, Hydrogen and Electricity generation www.raphael-project.org/index.html	19.8	9.0	AREVA NP	15/04/2005 14/03/2009
2	GCFR	The Gas Cooled Fast Reactor www.gcfr.org	3.6	2.0	NNC (UK)	01/03/2005 28/02/2009
3	HPLWR Phase 2	High Performance Light Water Reactor - Phase 2 www.hplwr.eu	4.6	2.5	FZK (DE)	01/09/2006 31/08/2010
4	ALISIA	Assessment of LIquid Salts for Innovative Applications	0.6	0.25	CEA (FR)	01/01/2007 31/12/2007
5	EISOFAR	Roadmap for a European Innovative SOdium cooled FAst Reactor	0.6	0.25	CEA (FR)	01/01/2007 31/12/2007
		Totals	29.2	14.0		

3. The EURATOM Seventh Framework Programme (FP7) (2007-2011)

Research and development activities in FP7 [3] comprise two themes: (i) Fusion Energy and (ii) Nuclear Fission and Radiation Protection. The FP7 objective in the latter area is to establish a sound scientific and technical basis in order to accelerate practical developments for the safer management of long-lived radioactive waste, enhancing in particular the safety performance, resource efficiency and cost-effectiveness of nuclear energy and ensuring a robust and socially acceptable system of protection of man and the environment against the effects of ionising radiation. Efforts are still required to ensure a continuation of the European Community's outstanding safety record. The key issues are operational reactor safety and management of long-lived waste. In addition, the individual technical areas are linked by key cross-cutting topics such as the nuclear fuel cycle, actinide chemistry, risk analysis and safety assessment and societal and governance issues. Research is also needed to explore new scientific and technological opportunities and to respond in a flexible way to new policy needs that arise during the course of the Seventh Framework Programme. The following activities are to be pursued. (a) Management of radioactive waste: Implementation-oriented research and development activities on all remaining key aspects of deep geological disposal of spent fuel and long-lived radioactive waste and, as appropriate, demonstration of the technologies and safety, and to underpin the development of a common European view on the main issues related to the management and disposal of waste. Research on partitioning and transmutation and/or other concepts aimed at reducing the amount and/or hazard of the waste for disposal is a priority. (b) Reactor systems: Research to underpin the continued safe operation of all relevant types of existing reactor systems (including fuel cycle facilities), taking into account new challenges such as life-time extension and development of new advanced safety assessment methodologies (both the technical and human element) including as regards severe accidents, and to assess the potential, the safety and waste-management aspects of future reactor systems, in the short and medium term, thereby maintaining the high safety standards already achieved within the EU and considerably improving the long-term management of radioactive waste. (c) Radiation protection: This topic is out of scope of this paper (d) Infrastructures: Support should be given to the availability of, and cooperation between, research infrastructures such as material test facilities, underground research laboratories, radiobiology facilities and tissue banks, necessary to maintain high standards of technical achievement, innovation and safety in the European nuclear sector. (e) Human resources, mobility and training: Support should be provided for the retention and further development of scientific competence and human capacity (for instance through joint training activities) in order to guarantee the availability of suitably qualified researchers, engineers and employees in the nuclear sector over the longer term.

Calls for proposals for the Euratom FP7 are made at a yearly interval. First, second and third calls of Euratom FP7 were made on 22 December 2006 and 30 November 2007 and 19 November 2008 respectively. A number of proposals in the area of P&T and Advanced reactor systems have been funded (see sections 3.1 and 3.2) and the projects are well underway.

3.1 The Research Activities on P&T in FP7

The projects in the area of P&T that were selected for funding in Euratom FP7 are given in Table 3. The reader is referred to each project's respective website for details of the objectives and results achieved and current status (see Table 3).

A 4-year project on partitioning **(ACSEPT**) was started on 1 April 2008 after the project EUROPART (FP6) was successfully completed. ACSEPT is 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. The project plans to optimise and select the most promising processes dedicated to actinide partitioning and those featuring a

Table 3: Euratom FP7 P&T projects underway indicating their salient features

SN	Acronym	Title	Budget (M€)		Co-ordinator	Start Date End Date
			Total	EC		
1	ACSEPT	Actinide Recycling by Separation and Transmutation http://www.acsept.org	23.8	9.0	CEA (FR)	01/04/2008 31/03/2012
2	GETMAT	Gen IV and Transmutation Materials http://nuklear-server.ka.fzk.de/getmat/index.php	14.0	7.5	FZK (DE)	01/03/2008 29/02/2013
3	EUFRAT	European Facility for Innovative Reactor and Transmutation Neutron Data http://irmm.jrc.ec.europa.eu/html/activities/eufrat/index.htm	0.5	0.5	JRC-IRMM (Mol-BE)	01/11/2008 30/09/2012
4	ACTINET-I3	ACTINET Integrated Infrastructure Initiative	~6.0	~3.0	CEA (FR)	Under Negotiation
5	FAIR-FUELS	Fabrication and, Irradiation and Reprocessing of Fuels and Targets for Transmutation (Website under construction)	6.5	3.0	NRG (NL)	01/02/2009 31/01/2013
6	CDT	Central Design Team for a Fast Spectrum Transmutation Experimental Facility (Website under construction)	5.0	2.0	SCK/CEN (BE)	01/04/2009 31/03/2012
		Totals	~55.8	~25.05		

group separation. Pyro-processes will be developed beyond the current state-of-the-art. All experimental results will be integrated by carrying out engineering and systems studies on aqueous and dry (pyro) processes to prepare for future demonstration at a pilot level.

GETMAT, is a 5-year project on materials that started on 1 March 2008. This cross-cutting project characterises materials for nuclear applications in the area of fission and fusion. The focus of GETMAT has been put on Ferritic-Martensitic (F/M) and Oxide Dispersion Strengthened (ODS) steels, as cross-cutting structural material choice for core and primary components. Moreover, the project aims to streamline the efforts on (i) availability, fabricability and fundamental properties, (ii) compatibility with coolants, (iii) response to irradiation and (iv) efforts to understand physical reasons for their behaviour under these conditions. Other priorities include joining and welding procedures qualification, development and definition of corrosion protection barriers and improved modelling and experimental validation.

EUFRAT is a 4-year transnational access project that started on 1 November 2008. Access of outside users to the GELINA and the Van de Graaff accelerator facilities of the Neutron Physics unit of JRC-IRMM, Geel is facilitated for neutron cross section measurements. Proposals for experiments submitted by external users are evaluated by an International Programme Advisory Committee. The project is expected to deliver new, more accurate neutron cross-section data in nuclear technology domains such as fission reactor technology, fission reactor and fuel cycle safety, high burn-up fuels, nuclear waste transmutation and innovative reactor systems.

The Integrated Infrastructure Initiative (I3) **ACTINET-I3** project is under negotiation. The objectives of ACTINET-I3 are (i) to establish a network of Actinide facilities across the EU to integrate and structure the way these Actinide infrastructures operate and to foster their joint development in terms of capacity and performance, (ii) to support and manage jointly a programme of access to appropriate infrastructures for training and associated research projects making use of the proposed facilities and (iii) to conduct on a limited scale a set of JRC Activities involving member organisations, with an objective to improve the performance of infrastructures by developing new relevant instrumentations and/or data of common interest. The project on Fabrication, Irradiation and Reprocessing of Fuels and targets for transmutation (**FAIRFUELS**) started on 1 February 2009. It aims to provide a way towards a more efficient use of fissile material in nuclear reactors and to reduce the volume and hazard of high level long-lived radioactive waste. In fabrication technology and assessment of transmutation performance, FAIRFUELS will focus on minor actinides. Dedicated fuels will be fabricated and a comprehensive irradiation programme will be carried out to address transmutation performance. Certain Post Irradiation Examinations (PIE) of earlier irradiated fuels and targets will also be conducted. In support of the PIE, modelling aspects of these fuels will be developed.

The aim of establishing a Central Design Team **(CDT**) for the design of a fast spectrum transmutation experimental facility (FASTEF) working in sub-critical (ADS) and critical modes is to demonstrate efficient transmutation. This is an essential next step just when the FP6-Eurotrans (see above) is completing its work successfully. There is also a clear need of an alternative technology to sodium. Therefore, FASTEF is designed to an advanced level using liquid lead technology. A possible decision to embark for its construction is expected around 2012 with the following objectives: to demonstrate the ADS technology and the efficient transmutation of high level waste; to operate as a flexible irradiation facility; to contribute to the demonstration of the Lead Fast Reactor technology without jeopardising the above objectives. The work to be carried out includes plant requirements and a study of key issues towards the realisation of such a facility as well as site specifications and licensing issues.

3.2 The Research Activities on Advanced Reactor Systems in FP7

The projects in the area of Advanced Reactor Systems that were selected for funding in Euratom FP6 are given in Table 4. The reader is referred to each project's respective website for details of the objectives and results achieved and current status (see Table 4)

F-BRIDGE: A new approach to fuel development based on fundamental understanding of fuel behaviour from atomic to macroscopic scale is proposed by the F-BRIDGE (Basic Research for Innovative Fuels Design for Gen IV systems) collaborative project. This approach will enable a rationalization of the design process, a better selection of promising

fuel systems, and will therefore reduce significantly the time and costs currently required for developing new fuels, as well as contribute to improving safety features of new systems under all operational and accidental conditions. This 4 year project started on 1 March 2008 with 20 partners. Its total budget is 10.2 million € with an EC contribution of 5.4 million €.

Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste **(CARBOWASTE)** project aims at an integrated waste management approach for this 'Intermediate Level Waste' containing C-14, Cl-36 etc. Successful results in this research will be directly applicable for the Very/High-Temperature Reactor (V/HTR) that is a promising Advanced Reactor system. Methodologies and databases will be developed for assessing different technology options like direct disposal in adopted waste containers, treatment & purification before disposal. The feasibility of the associated processes will be experimentally investigated to deliver data for modelling the microstructure and localization of contaminants.

Collaborative Project on European Sodium Fast Reactor **(CP-ESFR)** addresses key viability and performance issues to support its development leading to a demonstrator around 2020-25. The objectives are the improvement of safety level; provide competitive financial risk and a flexible and robust management of the nuclear materials. All associated technical requirements are dealt with by including fuel, fuel pins, core and fuel cycle, safety and security, and energy Conversion System Components and materials, reactor systems (including handling) and education and training. In the third call of FP7, a number of proposals (see Table 4) have been received that are under evaluation.

Table 4: FP7 Advanced Reactors projects underway

SN	Acronym	Title	Budget (M€)		Coordinator	Start Date End Date
			Total	EC		
	FP7-2007 Call					
1	F-BRIDGE	Basic Research for Innovative Fuel Design for Gen IV Systems	10.2	5.4	CEA (FR)	01/03/2008 29/02/2012
2	CARBO WASTE	Treatment and Disposal of Irradiated Graphite and other Carbonaceous Waste	12.0	6.0	FZJ (DE)	01/04/2008 31/03/2012
	FP7-2008 Call					
3	CP-EFSR	Collaborative Project on European Sodium Fast Reactor	11.5	5.8	CEA (FR)	01/02/2009 31/01/2014
		Totals	37	195.8		
	FP7-2009 Call: Potential Projects					
4	LEADER	Lead Cooled Advanced Demonstration Reactor	Proposals Received and under Evaluation			
5	GOFASTR	European Gas Cooled Fast Reactor				
6	ADRIANA	Advanced Reactor Initiative and Network Arrangement				

4. Discussion and Conclusions

Sustainability of nuclear energy requires that future electricity producing nuclear systems are integrated into a closed fuel-cycle. Future Generation IV fast-reactor systems have the potential to produce 50 to 100 times more electricity than current reactors for the

consumption of the same amount of uranium [5]. They are expected to produce significantly lower quantities of waste. P&T is expected to strongly minimise the waste legacy for geological disposal as compared to present reactors in terms of volume, thermal load and radiotoxic inventory.

A double-strata approach utilising energy producing reactors in conjunction with dedicated Sub-critical Accelerator Driven Systems (ADS) and/or Critical Fast Reactors (Gen IV systems) for waste transmutation has strong merits and has a good chance of achieving success. This scheme compartmentalises the tasks of electricity production and radioactive waste transmutation leading to an efficient implementation of both tasks fairly independently. It permits the Utility to concentrate on electricity production without jeopardizing its operation by unnecessarily further complicating its task by requiring it to transmute the waste in the same reactor. This additional task has a strong influence on the safety of energy producing critical fast reactor as well as it runs the risk of delays with the regulatory approval. The latter is highly constrained with the public safety and any innovation has to be systematically and safely demonstrated in a step-wise manner before the regulatory approval can be acquired. A dedicated waste transmutation system using an ADS and/or critical FR is therefore being considered. A decision on the choice is planned in a couple of years. Note that the geological disposal of the remaining waste (separation/transmutation losses) will nevertheless be necessary.

The efforts and resources that are presently being allocated to the study of P&T have an added value of training many researchers by supporting a rather large number of Ph.D. students through integrated projects. This will definitely contribute to the retaining and building of competence in the nuclear fission area. Moreover, even if ADS Systems are found to be inappropriate for future research in waste transmutation, the efforts devoted to fuel, technology and nuclear data research will to a large extent be directly applicable to lead-cooled fast critical systems.

A consistent set of shared cost projects funded by the Euratom Sixth and Seventh Framework Programmes, are covering different areas of P&T and Advanced Reactor systems. Adequate research infrastructures are essential for the future of nuclear energy, in particular Material Test Reactors to continuously meet the need of irradiation capabilities (with both thermal and fast neutron flux) in Europe. Education and training of young engineers and researchers is also important to maintain the high safety levels of nuclear installations in Europe, when the present generation is depleted through natural wastage.

The areas foreseen in the SRA of SNE-TP are those already covered by the Euratom Framework Programmes, namely Gen II, III and IV systems, advanced fuel cycles for waste minimisation, research infrastructures and cross-cutting topics. The SRA will be an important input for the Deployment Strategy and for the European Industrial Initiative on the development of Gen IV technologies.

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