
The Safety Research in the European Strategic Research Agenda (SRA) of the Sustainable Nuclear Energy Technology Platform (SNE-TP)

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Summary

The *Sustainable Nuclear Energy Technology Platform* (SNE-TP) was launched by the EC in the aim to constructing the European Research Area for nuclear fission at the horizon 2020 - 2050, and providing the deciders and the large public with a middle-long term vision on research and development needs, challenges and priorities.

The paper summarizes the sub-chapter of the SNE-TP *Strategic Research Agenda* (SRA) devoted to the investigation and definition of R&D needs in the current power reactor Safety assessment related fields.

An overview on the Safety concern for future reactors (GEN-IV) is also provided

1. Foreword

Applied research is mandatory for any scientific and/or technical achievement.

In a time of resurgence of nuclear industry, increasing competition and reduction of allocated resources, research must be organized and strategically oriented to avoid dispersion of effort and money and guarantee a full coverage of all the stakeholder needs, including design and production, but also safety, training and public information.

The current research programmes for reactors in operation and under construction should generate new knowledge, improve the public confidence for nuclear industry and support acceptance of its technology, as well as provide opportunity for training and driving newcomers to the nuclear field.

Safety research will involve new generation simulation tools and innovative experimental programmes, to be carried out both in the research facilities currently in operation worldwide and in new dedicated mock-ups either under construction or to be constructed. It will contribute to a safe and economical operation of current reactors and support the development of advanced and evolutionary systems (GEN-IV).

In the aim to constructing the European Research Area for nuclear fission, and providing the deciders and the large public with a middle-long term vision on research and development needs, challenges and priorities, the EC launched, in September 2007, the *Sustainable Nuclear Energy Technology Platform* (SNE-TP) [REF. 1, Fig. 1].

More than 60 Organisation from 17 European countries have already joined the SNE-TP. The SNE-TP governance system includes a Governing Board (GB), chaired by Mr. Philippe Pradel from the French CEA, that gathers all representatives of the partners and receives opinions from the states mirror group and from the European TSO Network. The Executive Committee (EXCOM) receives directions from the GB; it includes a limited number of

representatives that practically organise and lead the work programme of the platform through several working groups (WG) which are listed according to their starting time:

- The WG in charge of the *Strategic Research Agenda* (SRA) started at once with drafting the next 50 years programme to support research, development and demonstration for current and future NPPs (Nuclear Power Plants),
- The *Education, Training and Knowledge Management* (ETKM) WG started a few months later; it is aimed at issuing proposals to reinforce European education and attract youngsters in the nuclear field,
- The *Development Strategy* (DS) WG, in charge of defining the research-road-map implementation, started by mid 2008,
- The WG dedicated to funding will start when necessary.

The SRA WG started at the beginning of 2008 from the objectives defined in the SNE-TP Vision Document issued in September 2007 [REF.1]. A very intensive work will result in publishing the first draft of the SRA report by mid-November 2008.

The structure of the SRA includes 6 specific topics on the different existing or future reactor systems, while 5 other sub-groups on cross-cutting activities are meant to develop more generic research programmes applicable to all specific topics.

The SRA specific topics are [REF. 2]:

- ◇ Current and Future Light Water Reactors (including the ,
- ◇ Advanced Fuel Cycle for waste minimisation & resource optimisation,
- ◇ GEN IV Fast Spectrum Reactors (SFR, LFR, GFR, ADS),
- ◇ HTR and other applications of Nuclear Energy,
- ◇ New nuclear large research infrastructures;

And the cross-cutting topics:

- ◇ Structural material research,
- ◇ Pre-normative research, codes and standards.
- ◇ Modelling, simulation & methods (including physical data and tools and means for qualification and validation),
- ◇ Fuel Research
- ◇ Reactor safety (including severe accidents and human factor);

The reactor safety sub-group, coordinated by G.B. Bruna (IRSN) as a representative of the European TSO (Technical Safety Organisations) Network received contributions from nearly 40 participants (see the list in given Tab. 1).

The present paper, which as to be seen as a collective work,* has the objective of summarizing the SRA sub-chapter "Reactor safety", mainly focusing upon the most relevant medium-long term research and development concerns for current and under-construction reactors. An overview on the Safety concerns for future reactors (GEN-IV) is also provided

The organisations of several authors of this summary-paper belong to the TSO network participating jointly in the SRA; the others are either Safety Authorities or R&D Institute (PSI) deeply involved in R&D in support to the safety assessment.

These organisations are clearly engaged in continued safety research. They have expressed their commitment "*to contribute further to nuclear safety through evaluation of international operational feedback, through further improvement of safety analysis methods and tools, which will certainly require a continuous effort in Research and Development*".

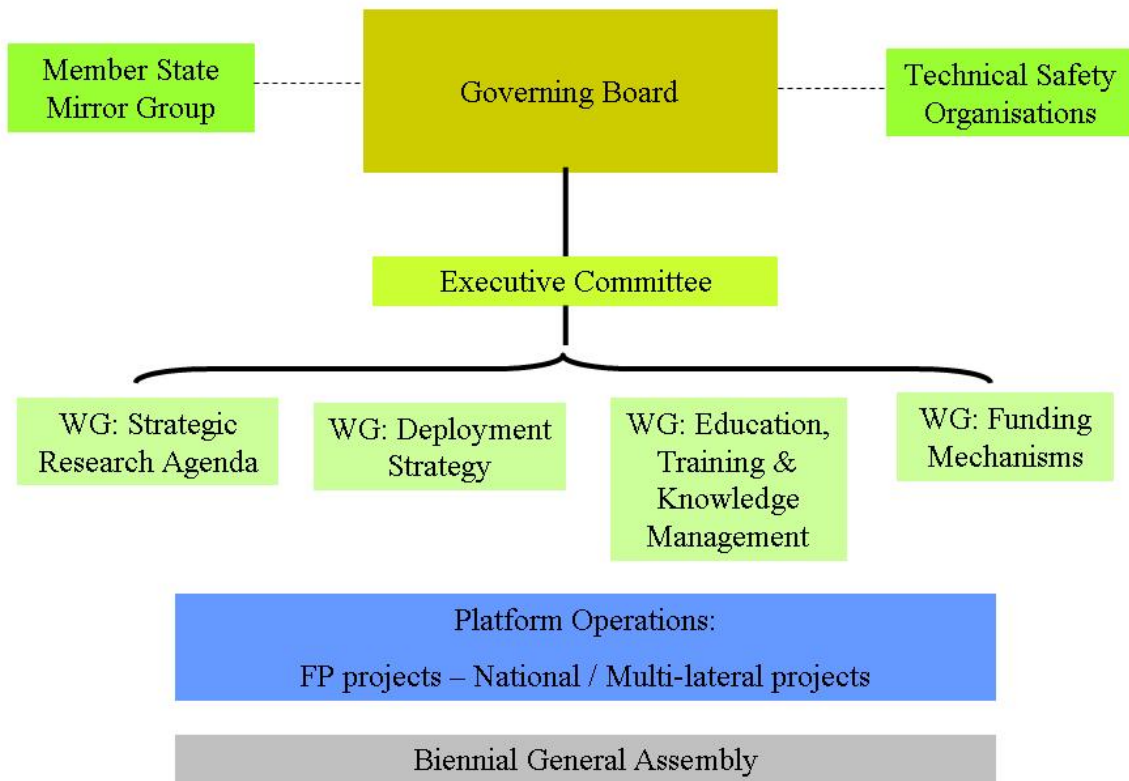


Fig. 1 The Sustainable Nuclear Energy Technology Platform (SNE-TP)

**The technical content of the work has been elaborated through a wide collaboration among all the SRA Safety sub-chapter Contributors. The authors are greatly indebted to all them for their precious work.*

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Tab. 1 List of SRA Safety sub-chapter contributors

2. Safety Research

The connection between safety research and regulation is crucial [REF. 3]. In view of limited resources, it is obvious that the first priority must be given to the activities that support the regulator in solving pending safety issues, but, beyond that, it is mandatory to maintain a sufficiently broad layer of basic research, which comprises the development of simulation tools, assessment methods, data banks and experimental programmes carried-out in dedicated facilities with their laboratory infrastructure.

Operating experience feedback contributes significantly to identify crucial needs for research, but sometimes research itself yields findings which motivate additional investigations. Experiments often give unexpected results or even allow disclosing hidden phenomena and variables.

Existing installations have obtained excellent performance records in the last decade. Even though the safety level already achieved can be maintained without investing new exhaustive research efforts, anticipation of further tighter requirements for even higher standard levels regarding public and environmental safety can be made. That asks for preparedness for new research in the future, involving new generation simulation tools and innovative experimental programmes, to be carried out both in the research facilities currently in operation worldwide and in new dedicated mock-ups. Enhanced or complementary data banks to be generated and further investigations on human and organisational factors will be the primary research activities, from which the end users definitely will profit.

The concept of “safety margins” [REF. 4] has been traditionally used with the ultimate goal of protecting the public and the environment from radiological hazards of potential releases from the Nuclear Power Plants (NPPs). It accounts for the uncertainty, either aleatory or epistemic, which affects the values of the safety variables. Protective and safety systems or features are intended either to preserve the integrity of these barriers or to mitigate the effects of their failures and should provide the necessary level of “safety margins”.

An extension of this concept has been recently proposed, based on the likelihood of incurring some damage in a particular event sequence, i.e., on the conditional probabilities of barrier failure (or bypass) leading to the damage. It is straightforward that the “safety margins” approach and more generally the development of probabilistic approaches will show-up in an increased need for new and very demanding research in the field of current NPPs, both from a theoretical as well as an experimental viewpoint, e.g. the international programmes addressing the behaviour of high burn-up fuel during accidents, in order to assess the validity of existing safety limits.

Beyond the immediate and anticipated needs, it will be very important to maintain sufficiently broad basic/fundamental research activities to back-up the application oriented research.

Final goal of the continued research is to sustain and expand the current level of the competence. Keeping the motivation of the researchers at a high level, for which challenging goals have to be set and maintained over a quite long time, is a prime prerequisite of success of the research at any time.

3. Motivation for Research in the Current Reactor Field

Increased competition in a deregulated electricity market demands for an optimized production: responding to this requirement, advanced fuel with new cladding materials has been designed to achieve higher burn-up, new fuel materials, such as MOX, have been introduced, more demanding loading patterns and advanced operation modes have been adopted, plant life-time has been increased and power has been up-rated in many NPPs. This trend, having an effect on safety margins, will continue and amplify in the future.

All the modifications adopted and the associated safety assessments are to entail research in several fields, including computer code development and extended experimental activity.

Moreover, experiments contribute to the knowledge because they participate in the validation of the computer code physical models and, sometimes, they may provide unexpected results which allow disclosing hidden phenomena and ignored variables.

In addition, significant efforts should be devoted to get the maximum benefit from the computation tools already in place. Their applicability should be extended to all types of current and future water cooled reactors and validated under the conditions of new designs. Such an "extrapolation" of the already gathered knowledge in the field of LWRs would maximize benefit from the work already done and could save some major efforts in the future.

Finally, some electricity-infrastructure wide problems (e.g. degrading stability of the international grid) - which are not specific to the nuclear industry, but have unacceptable impact on current NPP operation and threaten new plant siting - should be addressed, such as expanding the high-voltage transmission infrastructure and developing alternative cooling technologies.

4. Issues in Current Reactor Research and Development

The proposed main axes for research in the forthcoming future are summarized here below. It must be stressed that they are the combination and the consolidation of the somewhat contrasting needs of the stakeholders (utilities, safety authorities, technical support organisations, vendors, research organisations), whose priorities may be different. In some cases, the possibility of sharing is questionable, the research being of a competitive nature or for independence sake (as it could be the case for reactor physics computational chain).

Eventually, it is worth remembering that the investigation of future needs for safety research should not shadow the currently pending issues and hide no less important circumstances like disappearance of human competence and experimental facilities as an actual threat.

• Reactor Physics and Dynamics

The major incumbent challenge in the field should be the acquisition and the reinforcement of the fundamental knowledge, to enable the safety assessment of current reactor improved core loadings and advanced operations, as well as of evolutionary and advanced reactors and of experimental and test facilities.

Among the main fields of interest and endeavour, we mention:

- Generation of extended data libraries to include new materials and up-date existing data in energy regions relevant to safety analysis, as well as the generation of accurate covariances matrices (relevant to uncertainty analysis) for all relevant isotopes in the libraries,

- Improvements in the cross-sections generation processes,
- Up-dating the reference transient core-dynamic codes to include extended and more precise computation capabilities for pin-wise (or local) power distribution, temperature and moderator feed-back effects, kinetics parameters, control rod worth, poison worth, also to account for advanced and innovative fuel design, namely for BWRs, and inhomogeneous situations,
- Improvement of methodologies to reassess the reactivity limits vs. burn-up,
- Development, validation and generalisation of coupled computation chains, including neutronics, thermal-hydraulics, thermomechanics of fuel and primary circuit structures and the integral system simulation capabilities,
- Extension of uncertainty analysis capabilities, (through sensitivity, variational and perturbation tools).

● Thermal-Hydraulics

The main investigation and research issues in thermal-hydraulics should comprise the acquisition and the implementation of a sufficient knowledge to master the following phenomena and events for which many suitable data are already available, the harmonisation and the best practice development:

Accordingly, the short-term R&D challenges should include:

- Pressurized Thermal Shock, PTS, item intimately connected and relevant to the ageing issue,
- Inherent boron dilution in case of LOCA (LOss of Coolant Accident), if needed after OECD project (PKL),
- Re-flooding following LB-LOCA (Large Break-LOCA), investigation of which should be continued experimentally in the framework of fuel-related international programmes,
- Reactivity initiated accidents and related coupled computation tools,
- Main Steam Line Break (MSLB), both from theoretical and experimental viewpoint,
- Long term coolability of partly damaged core as a consequence of clad ballooning and fuel relocation,
- Development and assessment on thermal stratification, in extreme conditions, mainly for BWRs, as well for GEN-III systems.

For all these topics, the increased adoption of CFD codes will require definition of an adequate set of experiments to be carried-out with advanced instrumentation, as well as the continued development (and, if existing, the implementation) of specific user-oriented guidelines.

● Criticality

Risks of Criticality (and re-criticality) are of interest for normal operation safety assessment, as well as for incidental and accidental situations. At present, well qualified computation chains are in use worldwide. They underwent international benchmarks, and enjoy large and shared qualification, so that no specific needs should show-up in a foreseeable future. But, the changeover to innovative fuels and cycles will reveal new challenges for criticality safety assessment such as fuel characterisation, actinide content, new burnable poisons, innovative reprocessing methods, direct disposal of spent fuel, etc. An active feedback from the main actors in fuel design and cycle would be required to establish the future trend in criticality safety research. The current practice being based on prevention, the main safety concern addresses the consequences of a return to criticality in the pool. Accordingly, the following main actions can be asked for:

- Guaranteeing the maintenance and the up-dating of the computation chains and improving their user-friendliness and robustness,
- Enlarging validation including all freely available data,
- Codifying and structuring knowledge, including information from criticality accidents,
- Creating and implementing rigorous and physically based methodologies to establish safe, but not redundant, sub-criticality limits,
- Extending the corium re-criticality studies, through suitable programmes, including experimental ones, comprehensive of thermal-fluid-dynamics, chemical and criticality analysis,
- Challenging the future, defining new experimental programmes and providing code improvements for future reactor criticality study computation capabilities, including return to criticality accidents.

● Nuclear Fuel

The main research issues in the Nuclear Fuel field should include, at least:

- Fuel response in case of LOCA and RIA: the current R&D effort should be intensified, to account for the new fuels, the generalisation of high-burn-ups and the more demanding reactor operation practices. Research effort for RIA and LOCA should mainly address the development of experimental database for the assessment of fuel safety criteria at high burnup for new cladding materials for both UOX and MOX fuels. Current research programmes on LOCA and RIA should be continued and implemented relying on dedicated experimental facilities for experiments (for example, CABRI for RIA, JHR for LOCA in the future),
- Fuel response in case of a LOCA in the spent fuel pool or when loading, mainly because these accidents are now ascribed in the residual risk, and only few programmes are devoted to them.
- Implementation and assessment of a multi-scale approach of the fuel behaviour through:
 - The development of the simulation-tool cascade from the atomistic to the macro-scale, starting from molecular dynamics calculations covering very small sample sizes during very limited time scales up to kinetic Monte-Carlo calculations,
 - The interpretation, analysis and internalisation of the existing experimental results, The extrapolation and transposition of the experimental results,
 - The development of computation tools including advanced models on:
 - the plasticity of the fuel and the loss of ductility due to hydrogen uptake,
 - the Fission Gas behaviour in the fuel matrix,
 - the sensitivity of the anisotropy to the burn-up,
 - the clad behaviour, the coupling to thermal-hydraulics,
 - the development of models for new materials.

● Human and Organisational Factors

The objective for human and organizational factors is to enable developing, managing and storing a wide network of knowledge in support to the safety and radioprotection expertise in different fields of endeavour, with the following main challenges:

- Survey of the human and organizational practices in current reactor normal, degraded and incidental operation, and the definition of practices to share knowledge,
- Evaluation of the impact of staff reduction on safety,
- Extended research on the impact of subcontracting in human-issue sensitive industry, including non-nuclear one,

- Development and acquisition of knowledge on man-machine interface design and use,
- Formalization of practices and methods for the evaluation of human and organizational factors, including an adequate link to risk and “safety margins” studies.

The priorities mentioned in the SRA of the ETPIS (European Technology Platform for Industrial Safety) have also to be assessed. They are:

- Human and organisational factors in safety management, including operation feedback, resilience engineering, safety culture),
- Human centred design (for design and plant modifications),
- Integrated risk assessment and management systems (quantitative risk analysis, human performance, decision making with conflicting objectives ...).

● **I&C and Electrical Systems**

The short term R&D needs in the field are mostly related to the ageing of electrical and control systems. We mention:

- Development of test methods to predict ageing effects on I&C components,
- Harmonisation of ageing knowledge of I&C components,
- Searching for understanding environmental parameters which influence I&C ageing,
- Establishment of branch technical positions including architectural and technological aspects,
- Anticipation of new challenges and the follow-up of technology changes and improvements, such as the adoption of programmable digital automation components, the implementation of new technological solutions in I&C systems inclusive the Protection Systems of current plants.

● **Malevolent Acts and Natural Hazards**

In recent years, new threats are coming-up forcing to focus not only on internal hazards, but also on the destructive action of external agents, including the time. When assessing the safe behaviour of a system, a component or an equipment, its robustness and resistance to the aging-generated phenomena and to all kind of external aggressions (including flooding, extreme weather condition, fire and earth-quakes) is to be demonstrated. Ageing is mainly to be investigated in the framework of current plant-life-extension activities, but additional challenges arise from the inclusion of external aggressions and hazard, such as:

◇ **Integrity of Equipment and Structures**

The main safety-related research issues in the field should comprise two main families:

• **Civil Engineering Work Vulnerability**, including:

- Harmonisation of practices on the vulnerability to external dynamic loads,
- Vulnerability to ageing and degradation processes (including steel liner corrosion) through the analysis of phenomena contributing to the cracking of pre-stressed concrete vessels, the concrete work durability and the methods for cracking detection,
- Contribution of concrete structures to the confinement of radioactive substances;

• **Mechanical Equipment Degradation**, including:

- Improvement of the knowledge on phenomena governing the degradation modes of the mechanical components to master and anticipate their behaviour vs. ageing, external loads, etc., and to verify the suitability of maintenance programmes and in-service inspections,

- Development of methodologies to assess techniques for repair, mitigation and replacement of components,
- Development of innovative methods to test new materials, e.g. those resistant to cracking, corrosion and other degradation mechanisms,
- Effect of water chemistry on material ageing including knowledge on noble metal additive,
- Development of more efficient detection devices for non destructive in-service and maintenance examinations. This activity should be supported by suitable tests.

◇ **Fire Safety**

The main short-term research issues in the Fire Safety should be comprehensive of both experimental and analytical activities, including an increased development of suitable CFD codes, with extended modelling capabilities such as:

- Fire growth and propagation,
- Smoke and heat propagation,
- Possible unforeseen behaviour in smoke transport for different elements/compounds,
- Equipment vulnerability,
- Efficiency of mitigation strategies.

Harmonisation effort should be pursued in the medium-term.

● **Plant Simulation**

Existing plant-simulators are mainly confined to operator training and qualification for operation and accidental conditions in their qualification range.

The new generation plant-simulators should include operation outside their range of qualification to simulate internal and external hazards.

Three main functions should be achieved by these new plant simulators:

- Contribute to the design through the simulation of the transients and the actuation of the different safety and safeguard systems,
- Simulate the transients adopted to prepare the responses to emergencies and external hazards, and the exercises to preclude any reactivity release to the environment,
- Be used for teaching and personnel training.

All those functions will contribute to support the long-term operation of NPPs through the accommodation of internal (materials) and external (building functionalities) boundary conditions. These functions will be also relevant to the containment of radioactivity.

Accordingly, the development of new-generation plant simulators and the related R&D should be first priority in the mid-term.

● **Severe Accidents**

The work carried-out in the framework of the Severe Accident Research Network of Excellence (SARNET – 6th FP of the EC) concluded to a common view on the ranking of the research priorities in the field. The results were based on the outcome of the previous EURSAFE action (5th FP of the EC), the effort of benchmarking and qualification of the European Integral Severe Accident Code ASTEC, already an international reference, the results of several accident scenario calculations, and the recent research in the domain of the PSA.

Based on the six SARNET “high priority” issues, short-term future research should be focussed on:

- Molten Corium Concrete Interaction (MCCI): experimental activities and development of computation capabilities in the existing tools,
- Ex-vessel and in core corium cooling: experimental activities and development of computation capabilities also accounting for specific BWR needs,
- Melt relocation into water and ex-vessel Fuel-Coolant Interaction (FCI): mainly, continuation of the currently ongoing OECD SERENA 2 programme,
- Hydrogen mixing and combustion in containment: continuation of the OECD SETH2 programme (including suitable experiments and development of specific computation capabilities),
- Completion of the current programme on Iodine chemistry in RCS and containment,
- Air ingress and Fission Product (FP) release: treatment of the oxidising impact on FP release from the fuel elements (effect of high burn-up and MOX).

Besides the above listed items, the modelling in the ASTEC code should be extended in the medium-term to include the loss of water and air ingress in spent fuel pool scenarios. Moreover, extension of the application range of ASTEC code to the BWR is of high priority for end users in Europe.

Several organisations claimed the harmonization of the PSA level 2 practices among Safety Authorities, designers and operators. The activity, presently underway in the framework of the ASAMPSA-2 is to be sustained. Supporting extension to the dynamic field, would allow to account for the effect of the device and operator response-time variability. Furthermore, capabilities to perform off-site consequence analyses in support to emergency preparedness should be maintained.

In the medium-term, other criteria than PIRT tables should be developed to identify relevant phenomena to address, to make judgements independent on experts’ own feelings and interests. At least other methods should supplement the PIRT ones, lately used within EU and CSNI groups.

A major concern in the field remains the loss of unique experimental facilities such as the PHEBUS reactor, due to financial constraints and lack of international support. Moreover, some other facilities, such as MISTRA and KROTOS, are presently facing serious risk of decommissioning at the end of the current OECD programmes (SETH2, SERENA2). Keeping such kind of facilities in operation is necessary not only because they provide useful results for physical analysis, model improvement and code validation, but also because they provide the necessary support for training and contribute to attracting new people to the field.

• **Emergency Management**

Emergency management is always an integral part of large technologies and/or infrastructures such as nuclear energy. Many improvements were achieved in the field in the last 20 years, which resulted in operational procedures and tools for the early phase of an emergency.

This successful work has to be continued and extended in the short-term to the modelling of the longer term problems resulting in strategies for the long term rehabilitation of contaminated areas, through:

- Improvement of the modelling of the long term emergency management actions in agricultural and inhabited areas and develop a framework for the sustainable rehabilitation of contaminated areas.
- Improvement of the decision support systems to deal with new threats.

In the longer term, the high standard of emergency preparedness and management has to be kept even if resources might decrease with time. Therefore, it is worth implementing the European platform for decision support and emergency management including a scenario generator for the planning, performance and evaluation of exercises. This will strengthen the preparedness and planning as well as keep competence in this area.

A long term R&D challenge should be the development of a European platform for emergency management, too.

5. The GEN-IV Safety Concern

Operating experience of current NPPs can contribute significantly to identify crucial needs for further research in the fission reactor field for advanced and evolutionary systems such as the GEN-IV ones.

Actually, advanced and evolutionary reactors encompass a variety of different designs and operating modes. They span a very large set of configurations, including small and large size cores, fast-neutron and moderated spectra, gas, water and liquid metal cooling, each one matching more or less completely and comprehensively the objectives of the GEN-IV roadmap. Natural resource optimization and waste minimization are goals more likely affordable for systems with a fast neutron flux, such as SFR - Sodium fast Reactor -, GFR - Gas Fast Reactor - and LFR - Lead Fast Reactor -. On the other hand, graphite moderated, gas cooled high temperature reactors, such as the Very High Temperature Reactor (V/HTR), are more likely to be inherently safe; they also have the best potential for a diversified energy production (electricity, but also industrial heat and hydrogen).

In addition to the overall design, the core size and the operating modes and, in some cases, a strong coupling between the neutron and temperature fields which can show-up in some large-size systems, the fuel, the materials for internals and vessel, the coolant features generate urgent needs which are incentive for specific research. Looking ahead, the research needs for future concepts are to be investigated, disclosed, and emphasized very early, so that the delivery of computation tools and the issuance of experimental results could match the design and safety-assessment schedules [REFs 5 & 6].

Designers, utilities, regulators and researchers are presently facing a very open landscape as regards the industrial maturity of concepts. Accordingly, the risk exists that the research effort outcomes will show-up either quite poor or straightforward or false.

That is actually very challenging from the safety point of view, because, even if some common features can be found among several advanced and revolutionary designs (such as operation, fuel behaviour, transients and severe accidents, their consequences, and the ways to mitigate them, as it is the case for RIA, water or air ingress), the safety assessment is strictly tied to design features, the details of which are hardly disclosed and remain widely unknown for the most concepts at the present stage of development. Nevertheless, it might be worthwhile at this time to initiate exploratory studies aimed at establishing safety limits and criteria independent from the adopted technology.

Some features of the models which are most likely to be finally constructed and operated in Europe in a foreseeable future are analyzed in the SRA [REF. 2].

6. Concluding Remarks

The need for new experimental and simulation tool development, aimed at sustaining safety analyses and the role of Regulators, should be definitively focussed on a wider perspective: in the past, nuclear research activity was mainly carried out by vendors, aimed at either achieving or complementing their own know-how and only a limited amount of selected information was released to Safety Authorities and almost none to the general public.

Today, the awareness on safety needs is completely different: the public acceptance plays a key role and may strongly affect the profitability of an investment in the nuclear field, the cost of experimental activities calls for participation of partners at the international level. All of these factors require a new approach, aimed at making the research results available and enjoyable to the Authorities and even to the public.

Moreover, in order to be free and accessible to the Authorities and the Scientific Bodies, the simulation tools should be conceived so as to be really user friendly, to support their adoption and, as a consequence, the real dissemination of a nuclear knowledge and confidence, and of the capability of assessing the behaviour of NPPs under normal and abnormal conditions, to get a confidence on phenomena and a capability to manage nuclear technologies.

The sub-chapter “Reactor Safety” of the SNE-TP Strategic Research Agenda (SRA) is devoted to the investigation and definition of R&D needs in for Safety assessment of current and future reactors.

Its main items are outlined in this paper, mainly focussing on current reactor needs. A short overview on the Safety concern for future reactors (GEN-IV) is also provided.

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