

## Strategic Research Agenda of the MTA KFKI Atomic Energy Research Institute

The Strategic Research Agenda of the MTA KFKI Atomic Energy Research Institute (AEKI), is determined by the Mission Statement. It outlines the main research targets and tasks of the institute and includes also the strategy of research infrastructure development. The Annual Research Program of AEKI should be derived from the Strategic Research Agenda. The Strategic Research Agenda should be actualized every five years, or even more frequently if necessary.

### *I. Research required by nuclear technology development*

Nuclear energy can be utilized in any country only if parallel research is carried out. The research should aim at the local needs of developing nuclear energy however it should also lead to original results. This is especially important in Hungary, since a Soviet-designed power reactor will be still operated through decades in the country. AEKI has to organize the support from the budget of the Hungarian Academy of Sciences and the domestic and European grant systems to ensure the necessary funds for the institute's research work in reactor physics, thermo-hydraulics, fuel behavior, reactor materials structure, monitoring and simulation, as well as dosimetry and nuclear chemistry in the upcoming years.

The institute should concentrate on the following research topics in the next years:

- 1. The improvement of computer modeling of quasi-static fuel behavior*  
Modernization of the steady state fuel behavior code FUROM to solve high burn-up problems in FUROM. Elaboration of the FUROM validation database. Feedback the application experience into FUROM development.
- 2. Modernization of acceptance criteria and methodology of safety analysis*  
Experimental investigation of the coolability of VVER assemblies after LOCA. Experimental studies on hydrogen uptake of zirconium alloys in normal operation. Zirconium oxidation in hydrogen rich atmosphere. Development and application of the Best Estimate Plus Uncertainties methodology in safety analysis. Adaptation of the TRACE thermo-hydraulic system code.
- 3. Computer modeling of new fuel assemblies with burnable absorbers for the safety analysis, the VERONA core monitoring system and the training simulator*  
Checking the fuel design criteria by using the FUROM code. Modeling of hot subchannels specific to Gd-bearing fuel. DBA transient analysis. Transient fuel behavior calculations for new fuel assemblies. Prediction of assembly temperature on the basis of actual thermocouple measurements corrected by the results of mixing measurements. Extension of the VERONA system for cores with new fuel assemblies. Integration of the KIKO3D reactor kinetic code and the RETINA thermo-hydraulic code into the simulator.

4. *Development of methodologies for assessing uncertainties in core design, reactor operation and safety analysis*  
Analysis of uncertainties in modeling normal operation and transients. Uncertainties of reactor physics and thermo-hydraulic calculations. Validation of specific theoretical models.
5. *Burn-up credit investigations*  
Safety evaluation of storage and transport devices with a special attention to the effect of cross section uncertainties.
6. *Experimental validation of CFD methods and the utilization of CFD results in traditional thermo-hydraulic codes*  
Flow mixing measurements by using PIV and LIF for CFD validation purposes. Validation of the FLUENT CFD code to mixing experiments. Application of CFD for mixing problems. Use of CFD mixing calculation in ATHLET. Development of the lattice Boltzmann method. Fine scale modeling of two-phase flow. Study of turbulence by using particle methods. Numerical and theoretical investigation of the liquid-steam boundary.
7. *Experimental studies on extreme thermo-hydraulic phenomena and the use of results in safety and stress-strain analysis*  
Shock waves, turbulences, and development of the WAHA3 water hammer model. Experimental water hammer investigations and applications to Paks NPP primary lines. Effect of thermo-hydraulic fluctuations caused by turbulence on crack initiation. Stability limits in liquids and solid materials. Pressure dependence of phase transitions.
8. *Experimental studies of fuel components in extreme conditions (with non-irradiated fuel samples)*  
Experimental and theoretical studies on Zr corrosion. Experiments on softening kinetics of the cladding, re-orientation of hydrides due to hoop stress, cladding creep. Preparation and evaluation of Halden LOCA measurements, refining the fragmentation model. Investigation of high temperature phenomena. Experiments related to severe accident phenomena.
9. *Research of correspondence between the microscopic and macroscopic properties of reactor materials*  
Investigation of the applicability of local approach models. Setting limits and conditions for the applicability of PERFECT and DISFRAC calculations.
10. *Modelling of activity transport*  
Development of the HERMACT code. Adsorption/desorption on structural materials.
11. *Development of modern, custom-designed simulator systems*  
Development of simplified simulator systems. Real time modeling of plant systems.

*12. Development of reactor diagnostics systems and interpretation models*

Completing the development of the PAZAR system. Software development for interpreting the signals of the PAZAR system. Development of noise analysis methodology. Noise analysis of Paks NPP signals. Developing a leak detection system.

*13. Research of health and environmental risks*

Biological effects of low dose ionizing radiations. Environmental monitoring and modelling. Development radon detection and monitoring.

*14. Space dosimetry*

Maintenance of Pille flying on the ISS, the DIM dust detector and the SPM plasma monitor flying on the Rosetta Lander. Modernization of PorTL. Development of the 3-axis dosimeter TriTel. Investigation of cosmic rays by using solid state track detectors. Establishing the requirements for personal and environmental TL dosimetry.

*15. Isotope effects*

Investigation of isotope effects by using SANS.

*16. Process monitoring*

Participation in the activities of the MTO section of the Halden Reactor Project.

The infrastructure of nuclear research is partly given by the institute's experimental equipment and computers, but the contributions of the OECD Nuclear Energy Agency projects (first of all the Halden Reactor Project), the 7<sup>th</sup> EU Framework Program and the bi-lateral HAS-CEA co-operation are also significant. The staff members of the institute should extensively participate in the activities of OECD NEA committees and working groups, and the research targets of the institute should be continuously harmonized with those of OECD NEA. It is important to adjust the research program of the institute to the long term expectations of the Hungarian Atomic Energy Authority and the Paks NPP Company.

## ***II. Participation in solving strategic problems of the Hungarian energy sector***

Most probably, Paks NPP will receive the permission for extending the lifetime of the units with 20 years, since this is technically feasible, and, on the other hand, it is practically unavoidable from the point of view of the Hungarian power supply. The institute should participate in various safety related lifetime extension related projects in the next years, if the competence of the institute allows them. The following topics can be foreseen:

*1. Refining the PTS, p-T and other studies related to the integrity of the primary circuit*

Studies on thermal ageing. Coupled CFD and fracture mechanical calculations. Modelling local ageing effects. Modeling the WPS effect. Load history modeling. Propagated error of stress-strain curve approximations in fracture mechanical calculations. Improving the experimental determination of stress-strain parameters.

2. *Derivation of new Operating Limits and Conditions and Technical Specifications*  
Consolidating the operating limits on the basis of transient analysis and uncertainty considerations. Deriving limits for cooldown velocity from strength analysis.
3. *Preparation and implementation of mitigative Severe Accident Management*  
Potential errors in EOPs caused by the temperature measurement. Construction of the CERES test facility, experiments to measure the effectiveness of ex-vessel cooling.
4. *Completing the DBA analysis of Paks NPP*  
Analysis and upgrading of the containment ventilation systems. Validation of steam generator heat exchange models in the presence of non-condensable gases.
5. *Derivation of the dependencies between releases of radioactive materials and health effects*  
Dispersion and dosis calculations. Establishing dosis-release correlations for Paks NPP units similar to correlations proposed by EUR.
6. *Expert opinions on the storage and transportation of casks with damaged fuel*  
Evaluating the measurements on stored casks with damaged fuel. Participating in the preparations for transporting the casks with damaged fuel.

Paks NPP should solve the remained safety problems to receive the licence for lifetime extension. Consequently, on the medium run, the institute will not deal with safety problems of the plant, but rather with ageing related problems fitting in the competence of the institute. The following topics can be foreseen:

7. *Modernization of the training simulator and its upgrading for I&C reconstruction*  
Solving methodical problems of using the simulator for the preparation of I&C reconstruction.
8. *Various tasks related to I&C reconstruction*  
Contributing to the preparation and selected tasks of the I&C reconstruction.

It is almost sure that new nuclear units will be erected in Hungary. This is necessary not only to replace the VVER-440 units of Paks NPP in the 2030's, but also because of the irrevocable ageing of the traditional plants around 2020. Strengthening the Hungarian Electricity Works (MVM) seems to be the key question in this process, since only this company would be able to represent the real national interests regarding new nuclear units. Correspondingly, the institute intends to be involved as a partner of MVM in the preparatory works aiming at the construction of new nuclear units, even if it partially impedes other current tasks of the institute. The erection of new nuclear units will start a (public and expert) debate on the strategy concerning spent fuel and HLRW and the institute should participate in the preparation of this new strategy. The following research topics can be foreseen:

9. *Expert opinions contributing the establishment of new nuclear units in Hungary*  
Comparing various reactor systems. Fuel cycle and High Level Waste management considerations. Participating in the tendering process. Checking the fulfilment of European Utilities Requirements.

10. *Establishing the national knowledge centre on reprocessing, transmutation, actinide chemistry and partitioning, etc.*

Complex investigation of the fuel cycle. Research related to a particular partitioning technology. Studies on closing the fuel cycle and MOX utilisation.

11. *Comparative analysis of the environmental consequences of electric energy production modes*

Estimation of environmental consequences of various energy production cycles.

12. *Establishing an advanced code system for core physics and DBA calculations*

An advanced code system for core physics and DBA calculations is developed to provide the possibility to evaluate independently the safety of new NPP units.

The institute should fight for receiving tasks in forming the technical basis of the domestic utilization of renewable energy resources. The knowledge of the institute in the comparative studies on environmental effects can prove to be especially important. This part of the Strategic Research Agenda should be elaborated whenever a high level decision is made on the role of the institute in these developments.

### ***III. Technical support to the activities of safety authorities***

- The institute should continue to carry out tasks arising from its position as a Technical Support Organization of the Hungarian Atomic Energy Authority.
- The institute should be prepared to the era when the new Hungarian nuclear units will be licenced and various works will be ordered either by the HAEA or the vendor.
- The institute intends to be involved in technical support expert activities in advising the regulatory organizations of countries which start the use of nuclear energy only now.
- It would be desirable to elaborate a more convincing basis of civil defense of the country. The institute could play a significant role in this, but a principal change of the relationship between the present players is a pre-requisite of such works.

The research topics arising from these tasks can be only partly defined at this stage.

1. *Modernising the CERTA-VITA remote core monitoring system*

2. *Validation of the CATHARE thermo-hydraulic code*

Preparing CATHARE analyses for the Paks NPP units. Developing and validating models for the potential new Hungarian nuclear units. Updating the CATHARE code version.

3. *CFD code validation*  
Participating in various OECD NEA projects. Validating CFD calculations to thermo-hydraulic experiments.
4. *Validating the TRANSURANUS code to measurements*  
The TRANSURANUS fuel behavior code should be validated to LOCA and other measurements made at Halden and at the MIR reactor.
5. *Studies on closing the fuel cycle*  
Studies are elaborated concerning intermediate and final disposal of spent fuel and high activity radioactive waste. Studies are prepared on reprocessing technologies.
6. *New developments in LOCA rules*  
Investigation of the parameters of TVEL cladding manufactured by new technology. Consequences of the new NRC LOCA rules to the VVER fuel.

#### ***IV. International co-operation in the research of new generation nuclear power plants***

The nuclear research in Europe and worldwide is highly motivated by the research works aiming at new generation nuclear power plants. The institute should be involved in this joint research regarding one or two reactor types. This can be facilitated by the extensive participation of the institute in the “Sustainable Nuclear Energy” Technological Platform of EU. The institute should be involved in research works in the following fields:

1. *Neutronics, thermo-hydraulics and safety studies for SuperCriticalWaterReactor*  
SCWR core optimization. Development of a fine mesh code for SCWR core calculations. Complex NDT studies characterizing the properties of SCW. Corrosion of structural materials in SCW. Heat transfer and critical flow in SCW. Investigation of the normal – supercritical transition. Safety analysis of SCWR.
2. *Neutronics, safety and fuel cycle studies for fast reactors and for a combined fleet of thermal and fast reactors*  
Reactor physics and fuel utilization in new reactors. Investigation of the fuel cycle by combining various reactor systems. Development of reactor physics codes for fast reactor calculations (multi-group version of the KIKO3D reactor kinetics code). Investigations on the thermo-hydraulic properties of gas cooled reactors.
3. *Development and investigation of new structural materials applicable in new reactor types*  
Development of reinforced steels. Development of ceramics for nuclear applications. High temperature corrosion of reactor materials under mechanical loads. Mathematical description and modelling of the radiation damage of steels.

4. *Development of multi-physics (neutronics + thermo-hydraulics + fuel behavior) simulation tools*

Study of 2D effects in heat conduction. Coupling between reactor physics, steady state fuel heat conductance and hot channel codes. Coupling of the hot channel code TRABCO and the transient fuel behavior code FRAPTRAN for RIA calculations.

The establishment of large European nuclear infrastructures is a major contribution to the sustainability of the peaceful use of nuclear energy. This development is a very demanding task where the participation of the institute would be very desirable, however, the research topics arising from this task cannot be well defined at this stage.

5. *Studies related to large research facilities (ESS, JHR, ITER)*

Environmental evaluation of large research facilities. Shock waves and cavitation in the Hg target of ESS. ESS related research. Radiation damage of electronic devices of ITER.

## ***V. Operating the research reactor and the related tasks***

- The institute should operate the research reactor in a safe and undisturbed manner also in the future. This requires a highly dedicated work of the institute leaders and the reactor staff. The most important task of the next period is to carry out the transportation of spent fuel to Russia and the transition to the operation with low enriched fuel. To solve this task, a large series of diplomatic, financial, technical and licencing problems has to be solved.
- The institute should motivate the participants of the Budapest Neutron Centre to utilize the recently largely improved measuring potential around the reactor. The development of the research infrastructure should be decided upon, taking into consideration the planned lifetime of the reactor (by 2023). The financial conditions of this program should be ensured by the institute together with the other participants of BNC.

Every task listed below requires the activity of researchers:

1. *Operating the BNC, participating in EERRI*
2. *Operating the radiography laboratory*
3. *Operating the activation analysis laboratory*
4. *Operating the irradiation facility BAGIRA*
5. *Using the Electron Microscope for various investigations*
6. *Operating the biological beam*
7. *Core design calculations*

8. *Control of water chemistry*
9. *Preparing the final deposition of beryllium*
10. *Modernisation of the Environmental Monitoring System. Modernisation of the Mobile Dosimetry Laboratory.*
11. *Developing emergency preparedness. The use of dosimetry in emergency preparedness.*
12. *Developing the quality management of the dosimetry services*
13. *Introducing a new vibration diagnostic tool*
14. *Manufacturing a new set of of absorber rods*
15. *Cleaning the spent fuel storage facility*
16. *Preparing the second transport of spent fuel to Russia*

**Approved by the institute's Scientific Council, on November 4, 2008.**