Economic and technical aspects of the nuclear fuel cycle

Advanced Nuclear Fuel Cycles and Radioactive Waste Management
This study analyses a range of advanced nuclear fuel cycle options from the perspective of their effect on radioactive waste management policies. It presents various fuel cycle options which illustrate differences between alternative technologies, but does not purport to cover all foreseeable future fuel cycles. The analysis extends the work carried out in previous studies, assesses the fuel cycles, and covers high-level waste repository performance for the different fuel cycles considered.

The estimates of quantities and types of waste arising from advanced fuel cycles are based on best available data and experts' judgement. The effects of various advanced fuel cycles on the management of radioactive waste are assessed relative to current technologies and options, using tools such as repository performance analysis and cost studies.

French R&D on the Partitioning and Transmutation of Long-lived Radionuclides
An International Peer Review of the 2005 CEA Report
ISBN 92-64-02296-1 Free: paper or web.
For many politicians and members of the public, the very long life of some of the radionuclides in radioactive waste is an issue of particular importance in terms of its ultimate disposal. The developing techniques of partitioning (isolating specific radioactive elements) and transmutation (re-irradiating them in order to convert them to shorter-lived or stable elements) hold the promise of eliminating or greatly reducing the long-lived radioactivity, bringing with it other technical benefits.

In France, the 1991 Waste Act required inter alia a research and development programme on partitioning and transmutation, with a milestone for review in 2006. The French authorities requested the OECD/NEA to organise an independent, international peer review of the results of this extensive research and development programme, with a view to help inform the parliamentary decision-making process on the way forward for radioactive waste disposal in France. This report presents the findings from that review, which was conducted by ten of the foremost international experts in the field.

Nuclear Energy Data: 2006 Edition
ISBN 92-64-02489-1 € 30, $ 40, £ 21, ¥ 4 100.
2005 was a year of major activity within the nuclear sector. Interest in nuclear energy is growing significantly in many OECD member countries with the construction of new plants, new plans for nuclear futures along with innovations in enrichment and reprocessing. This and other insights related to nuclear energy can be found in Nuclear Energy Data, the Nuclear Energy Agency’s annual compilation of essential statistics to 2025 on nuclear energy in OECD countries. The compilation provides readers with a comprehensive and easy-to-access overview of the
current situation and expected trends in the various sectors of the nuclear fuel cycle.

**Uranium 2005: Resources, Production and Demand**

*A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency*

ISBN 92-64-02425-5  € 120, $ 150, £ 82, ¥ 16 700.

Since 2001 the price of uranium has steadily climbed over five-fold, at a rate and reaching heights not seen since the 1970s. As a result, the uranium industry has seen a surge of activity, ending a period of over 20 years of relative stagnation. Worldwide exploration expenditures in 2004 increased almost 40% over 2002 figures. Overall, resource totals have increased over the past two years, indicating that increased uranium prices have begun to have an impact. Based on patterns observed following previous periods of heightened exploration efforts, further additions to the uranium resource base are anticipated given the recent dramatic increase in exploration expenditures. In 2004, significant production increases (>30%) were recorded in Australia, Kazakhstan and Namibia, while more modest increases (between 5% and 15%) were recorded for Brazil, Niger, the Russian Federation and Uzbekistan. Significant expansions are also planned in future production capacity in Australia, Canada and Kazakhstan. This very dynamic and major expansion of production capability could significantly alter the supply and demand relationship of recent years, provided planned centres are constructed on schedule and successfully reach full production capacity. Clearly, major changes in the uranium industry are under way, driven by recent uranium price increases.

The "Red Book", jointly prepared by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, is a recognised world reference on uranium. It is based on official information received from 43 countries. This 21st edition presents the results of a thorough review of world uranium supplies and demand as of 1st January 2005 and provides a statistical profile of the world uranium industry in the areas of exploration, resource estimates, production and reactor-related requirements. It provides substantial new information from all major uranium production centres in Africa, Australia, Central Asia, Eastern Europe and North America. Projections of nuclear generating capacity and reactor-related uranium requirements through 2025 are provided as well as a discussion of long-term uranium supply and demand issues.

**Nuclear safety and regulation**

**Building, Measuring and Improving Public Confidence in the Nuclear Regulator**

*Workshop Proceedings, Ottawa, Canada 18-20 May 2004*


An important factor for public confidence in the nuclear regulator is the general public trust of the government and its representatives, which is clearly not the same in all countries. Likewise, cultural differences between countries can be considerable, and similar means of communication between government authorities and the public may not be universally effective.

Nevertheless, this workshop identified a number of common principles for the communication of nuclear regulatory decisions that can be recommended to all regulators. They have been cited in particular for their ability to help build, measure and/or improve overall public confidence in the nuclear regulator.

**Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System**

*2002-2005*


The Incident Reporting System (IRS) is an essential element of the international operating experience feedback system for nuclear power plants. The IRS is jointly operated and managed by the Nuclear Energy Agency (NEA), a semi-autonomous body within the Organisation for Economic Co-operation and Development (OECD), and the International Atomic Energy Agency (IAEA), a specialised agency within the United Nations system.
Regulatory Challenges in Using Nuclear Operating Experience

ISBN 92-64-01083-1  Free: paper or web.

The fundamental objective of all nuclear safety regulatory bodies is to ensure that nuclear utilities operate their plants in an acceptably safe manner at all times. Learning from experience has been a key element in meeting this objective. It is therefore very important for nuclear power plant operators to have an active programme for collecting, analysing and acting on the lessons of operating experience that could affect the safety of their plants.

NEA experts have noted that almost all of the recent, significant events reported at international meetings have occurred earlier in one form or another. Counter-actions are usually well-known, but information does not always seem to reach end users, or corrective action programmes are not always rigorously applied. Thus, one of the challenges that needs to be met in order to maintain good operational safety performance is to ensure that operating experience is promptly reported to established reporting systems, preferably international in order to benefit from a larger base of experience, and that the lessons from operating experience are actually used to promote safety.

This report focuses on how regulatory bodies can ensure that operating experience is used effectively to promote the safety of nuclear power plants. While directed at nuclear power plants, the principles in this report may apply to other nuclear facilities as well.

Radiological protection

The Process of Regulatory Authorisation

A Report by the CRPPH Expert Group on the Regulatory Application of Authorisation (EGRA)


Governments and regulatory authorities are responsible for the definition of regulatory controls or conditions, if any, that should be applied to radioactive sources or radiation exposure situations in order to protect the public, workers and the environment. Although countries use different policy and structural approaches to fulfil this responsibility, the recommendations of the International Commission on Radiological Protection (ICRP) are generally used as at least part of the basis for protection. Previously, the ICRP recommended the use of variable approaches to protection. New ICRP recommendations are proposing a single, conceptually simple and self-coherent approach to defining appropriate protection under all circumstances.

While the ICRP has been reviewing the broad principles of protection, the NEA Committee on Radiation Protection and Public Health (CRPPH) has been focusing its efforts on how radiological protection could be better implemented by governments and/or regulatory authorities. To this end, the CRPPH has developed a concept that it calls “the process of regulatory authorisation”. It is described in detail in this report, and is intended to help regulatory authorities apply more transparently, coherently and simply the broad recommendations of the ICRP to the real-life business of radiological protection regulation and application. In developing this concept, the CRPPH recognises the importance of an appropriate level of stakeholder involvement in the process.

Occupational Exposures at Nuclear Power Plants – 2004

Fourteenth Annual Report on the ISOE Programme, 2004


The ISOE Programme was created by the OECD Nuclear Energy Agency in 1992 to promote and co-ordinate international co-operative undertakings in the area of worker protection at nuclear power plants. The programme provides experts in occupational radiation protection with a forum for communication and exchange of experience. The ISOE databases enable the analysis of occupational exposure data from 478 operating and shutdown commercial nuclear power plants participating in the programme (representing some 90% of the world’s total operating commercial reactors).

The Fourteenth Annual Report of the ISOE Programme summarises achievements made during 2004 and compares annual occupational exposure data. Principal developments in ISOE participating countries are also described.
Radioactive waste management

Disposal of Radioactive Waste: Forming a New Approach in Germany
FSC Workshop Proceedings, Hitzacker and Hamburg, Germany, 5-8 October 2004

Germany is exploring a new approach towards the final management of its radioactive waste. This international workshop, held in Germany, attracted 65 participants from 13 countries. A little more than half of the participants were German stakeholders. During the workshop invited speakers, representing different groups of stakeholders, commented on relevant aspects of the new German approach being proposed. This served as a basis for subsequent round-table discussions.

These proceedings provide a historical introduction to radioactive waste management in Germany, give a detailed summary of the workshop presentations and discussions that took place, and also provide the NEA Secretariat’s reflections which help place the main lessons of the workshop into a wider perspective. Five presentations – the three keynote papers and the two thematic reports – are also reproduced herein.

Nuclear Science and the Data Bank

Benchmark on the KRITZ-2 LEU and MOX Critical Experiments
Final Report
ISBN 92-64-02298-8 Free: paper or web.

The plutonium produced during the operation of commercial nuclear power plants or that has become available from the dismantlement of nuclear weapons needs to be properly managed. One important contribution to the management process consists in validating the calculation methods and nuclear data used for the prediction of power in systems using mixed-oxide (MOX) fuel. A series of computational physics benchmarks and issues regarding multiple recycling in various MOX-fuelled systems have been studied and published by the NEA. This has led to improvements in the nuclear data libraries and calculation methods. Full validation requires comparing those findings with data from experiments. The experiment at the KRITZ research reactor in Sweden is being used for this purpose.

This report provides an analysis of the 12 sets of results supplied by 16 experts from 7 countries, together with the comparison against the KRITZ evaluated experimental data. The report concludes...
that the computer codes and cross-sections used by
the participants, which are presently in widespread
use, can adequately predict the multiplication factor
and pin-power distributions of the MOX cores.

This report will be of particular interest to reactor
physicists and designers as well as to nuclear power
plant utilities.

**Computer Simulation of MASURCA**

**Critical and Subcritical Experiments**

**MUSE-4 Benchmark – Final Report**

ISBN 92-64-01086-6 Free: paper or web.

The efficient and safe management of spent fuel aris-
ning from the operation of commercial nuclear power
plants is an important issue. In this context, the par-
titioning and transmutation (P&T) of minor actinides
and long-lived fission products can play an important
role, reducing significantly the burden on geological
repositories of radioactive waste and enabling their
more effective use.

International interest in accelerator-driven systems
(ADS) has been expressed due to their potential use in
the transmutation of minor actinides. However, much
R&D work is still required in order to demonstrate the
desired capability of the system as a whole, and the
current methods of analysis and nuclear data for minor
actinide burners are not as well established as those
for conventionally fuelled systems.

A series of theoretical ADS physics benchmarks has
thus been organised by the NEA. Many improvements
and clarifications in nuclear data and calculation
methods have been achieved. However, following an
initial series of benchmarks, some significant discrep-
ancies in important parameters were not fully under-
stood and still required clarification. Hence, the first
experiment-based benchmark using MASURCA critical
and subcritical experiments (called MUSE-4 experi-
ments) was launched.

This report provides an analysis of the benchmark
results supplied by 16 institutions from 14 countries.
The calculated results were compared against experi-
mental data, whenever available. This report will be
of particular interest to reactor physicists and nuclear
data evaluators developing nuclear systems, especially
ADS, for radioactive waste management.

**NUPEC BWR Full-size Fine-mesh**

**Bundle Test (BFBT) Benchmark**

**Volume I: Specifications**


Refined models for best-estimate calculations based
on good-quality experimental data can improve the
understanding of phenomena and the quantification of
margins for operating nuclear power reactors.

According to experts, refinements should not be
limited to currently available macroscopic approaches
but should be extended to next-generation approaches
that focus on more microscopic processes. Multi-
scale/multi-physics approaches are the way forward
in this respect.

This report describes the specification of an
international benchmark based on high-quality
fine-mesh data, released through the government of
Japan and the Nuclear Power Engineering Corporation
(NUPEC), with the aim of advancing the insufficiently
developed field of two-phase flow theory. It has been
designed for systematically assessing and comparing
different numerical models used for predicting
detailed void distributions and critical powers.

Additional volumes concerning this benchmark
are planned and are intended to show to what extent
the most recent approaches are capable of predicting
two-phase flow phenomena.

**PENELLOPE-2006: A Code System for**

**Monte Carlo Simulation of Electron**

**and Photon Transport**

**Workshop Proceedings, Barcelona, Spain,**

**4-6 July 2006**

ISBN 92-64-02301-1 Free: paper or web.

Radiation is used in many applications of modern tech-
nology. However, its proper handling requires compe-
tent knowledge of the basic physical laws governing its
interaction with matter. To ensure its safe use, appro-
priate tools for predicting radiation fields and doses, as
well as pertinent regulations, are required.

One area of radiation physics that has received
much attention concerns electron-photon transport in
matter. PENELLOPE is a modern, general-purpose Monte
Carlo tool for simulating the transport of electrons and
photons, which is applicable for arbitrary materials and
in a wide energy range. PENELLOPE provides quantitative
 guidance for many practical situations and techniques,
including electron and X-ray spectroscopies, electron
microscopy and microanalysis, biophysics, dosimetry,
medical diagnostics and radiotherapy, and radiation
damage and shielding.

These proceedings contain the extensively revised
teaching notes of the latest workshop/training course
on PENELLOPE (version 2006), along with a detailed
description of the improved physics models, numerical
algorithms and structure of the code system.

**Physics and Safety of Transmutation**

**Systems**

**A Status Report**

ISBN 92-64-01082-3 Free: paper or web.

The safe and efficient management of spent fuel from
the operation of commercial nuclear power plants is
LWRs presents different neutron characteristics, the
present benchmark was launched in 2004 using the
measured data of the VENUS-2 MOX-fuelled critical
experiments. This report provides an analysis of the
results supplied by 12 participants from 7 countries.
The results have revealed that the computer codes and
nuclear data currently used for MOX-fuelled systems
in OECD/NEA member countries appear able to produce
results with a sufficiently high level of accuracy in
dosimetry calculations. This report will be of particular
interest not only to reactor physicists and nuclear
data evaluators, but also to nuclear utilities.

VENUS-2 MOX-fuelled Reactor
Dosimetry Calculations

Final Report

It is essential to calculate the structural integrity of
reactor components with a high degree of accuracy
in order to make correct decisions regarding plant
lifetime at the design stage, safety margins and
potential plant life extensions. The OECD Nuclear
Energy Agency (NEA) is therefore organising a series
of benchmarks to verify the current international
level of accuracy in pressure vessel fluence cal-
culations and to clarify the relative merits of various
methodologies. By extension, this enables the
identification of areas for possible improvements in
the various calculation schemes.

As a follow-up to the previous UO₂-fuelled
VENUS-1 two-dimensional (2-D) and VENUS-3 three-
dimensional (3-D) benchmarks, and given that many
commercial nuclear power plants in Europe and in
Japan use MOX fuel and that the use of MOX fuel in

an important issue. Worldwide, more than 250 000
tons of spent fuel from currently operating reactors
will require disposal. These numbers account for only
high-level radioactive waste generated by present-day
power reactors.

Nearly all issues related to risks to future
generations arising from the long-term disposal of
such spent nuclear fuel is attributable to only about
1% of its content. This 1% is made up primarily of
plutonium, neptunium, americium and curium (called
transuranic elements) and the long-lived isotopes of
iodine and technetium. When transuranics are removed
from discharged fuel destined for disposal, the toxic
nature of the spent fuel drops below that of natural
uranium ore (that which was originally mined for the
nuclear fuel) within a period of several hundred to a
thousand years. This significantly reduces the burden on
geological repositories and the problem of addressing
the remaining long-term residues can thus be done in
controlled environments having timescales of centuries
rather than millennia stretching beyond 10 000 years.

Transmutation is one of the means being explored
to address the disposal of transuranic elements. To
achieve this, advanced reactor systems, appropriate
fuels, separation techniques and associated fuel cycle
strategies are required.

This status report begins by providing a clear
definition of partitioning and transmutation (P&T),
and then describes the state of the art concerning the
challenges facing the implementation of P&T, scenario
studies and specific issues related to accelerator-driven
systems (ADS) dynamics and safety, long-lived fission
product transmutation and the impact of nuclear data
uncertainty on transmutation system design. The report
will be of particular interest to nuclear scientists
working on P&T issues as well as advanced fuel cycles
in general.

VVER-1000 Coolant Transient
Benchmark

Phase 1 (V1000CT-1), Volume 2: Summary
Results of Exercise 1 on Point Kinetics Plant
Simulation
ISBN 92-64-02295-3 Free: paper or web.

In the field of coupled neutronics/thermal-hydraulics
computation there is a need to enhance scientific
knowledge in order to develop advanced modelling
techniques for new nuclear technologies and concepts,
as well as current applications.

The present volume, a follow-up to the first volume
describing the specification of the benchmark,
presents the results of the first exercise that identifies
the key parameters and important issues concerning
the thermal-hydraulic system modelling of the
simulated transient. This exercise aims to achieve the
correct initialisation and testing of the system code
models. The transient chosen for the exercise is caused
by the switching on of a main coolant pump while the
other three are in operation. It is based on an
experiment that was conducted by Bulgarian and
Russian engineers during the plant commissioning
phase at the VVER-1000 Kozloduy Unit 6.

VVER-1000 MOX Core Computational
Benchmark

Specification and Results

The United States and the Russian Federation have
each agreed to dispose of 34 tonnes of weapons-grade
plutonium that are beyond their defence needs. One
effective way to dispose of this plutonium is to
convert it into mixed-oxide (MOX) fuel, burn it in a
nuclear reactor and use it to produce electricity.

This report describes an international benchmark
study that compared the results obtained for six
different states in a VVER-1000 reactor core loaded
with one-third MOX fuel. This NEA activity contributes
to the computer code certification process and to the
verification of calculation methods used in the Russian
Federation.