The OECD Nuclear Energy Agency at 50

BY GAIL H. MARCUS

As the OECD Nuclear Energy Agency celebrates its 50th anniversary, it is appropriate to consider its contributions over the last half-century, and its prospects for the future.

THE OECD NUCLEAR Energy Agency (NEA), which first opened its doors 50 years ago this month, began its existence as a much different entity than it is today, and in a different environment.

In the mid-1950s, the Organization for European Economic Cooperation (OEEC), originally chartered to administer the Marshall Plan for the post–World War II recovery of Europe, sought to address increasing European concerns about an energy supply shortage. While the United States, which had funded the Marshall Plan, participated in OEEC activities, the organization's membership and focus at that time were strictly European. (In 1961, the membership of the OEEC would expand and its name would be changed to the Organization for Economic Cooperation and Development. The OECD today has 30 members, including the United States.)

In December 1953, the OEEC Council, the governing body of the OEEC, commissioned a report to identify solutions to Europe's energy problems. That report, submitted to the council in May 1955, focused on the potential of nuclear energy and highlighted the importance of European cooperation in this field. In response to this report, in 1956 the council established a temporary working group and, later, a permanent body, the Steering Committee for Nuclear Energy, to identify potential areas of activity for the OEEC. This in turn led to a decision by the OEEC Council in 1957 to establish the European Nuclear Energy Agency (ENEA) under the OEEC. Its statute entered into force on February 1, 1958.

The original membership of the ENEA included all 17 countries that were OEEC members at the time of the ENEA's founding: Austria, Belgium, Denmark, France, West Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland, Turkey, and the United Kingdom. (Spain was not a member of the OEEC at that time but joined the OEEC and the ENEA shortly thereafter.) Since this was a European organization, countries in other parts of the world were not members. The United States and Canada, however, participated as associate members.

The ENEA was designed to provide a mechanism for peaceful nuclear cooperation. The agency had three primary objectives: the establishment of joint research projects; the solution of specific legal problems related to nuclear energy through the harmonization of national laws or the adoption of regional conventions; and the provision of a forum in which the national nuclear energy programs of its member countries could be discussed and coordinated.

It should be pointed out that the ENEA was born during a period of great excitement about the potential for nuclear power. The 1950s were also the formative years for a number of nuclear activities and institutions, and, in particular, marked the beginnings of two other important international, intergovernmental organizations that are still active today: the European Atomic Energy Community (Euratom), headquartered in Brussels, Belgium, and the International Atomic Energy Agency, located in Vienna, Austria. Both actually predate the ENEA slightly, having been established in March and July of 1957, respectively. The three organizations have distinct but overlapping roles, missions, and memberships. A variety of coordinating efforts, including participation in each other's meetings, joint projects, and management reviews, help ensure that the efforts of the three organizations are complementary.

Initial activities of the ENEA

The earliest activities of the ENEA actually preceded the formal establishment of the agency. Even as the discussions that would lead to the formation of the ENEA were under way, the OEEC Council was providing an early response to selected needs for work in the nuclear area as they were identified. Targeted committees under the aegis of the OEEC were formed in two areas–nuclear liability, and radiation protection. Both committees were subsumed into the ENEA when it formally came into being.

The first of these committees, now the Nuclear Law Committee, was initially established by the Steering Committee as a working group in January 1957. Eleven members of the OEEC joined the effort. This working group soon evolved into the

Gail H. Marcus (<ghmarcus@aol.com>) was the deputy director-general of the OECD Nuclear Energy Agency from April 2004 through March 2007. Prior to joining the NEA, she was the principal deputy director of the U.S. Department of Energy's Office of Nuclear Energy, Science and Technology. She also served as the 2001–2002 president of ANS.

Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy, which first met in January 1958. The group continued to operate under this name until October 2000, when the NEA Steering Committee finally changed its name and mandate and it became the Nuclear Law Committee.

The very first activity of the group, the drafting of the Paris Convention on Third Party Liability in the Field of Nuclear Energy (the "Paris Convention"), remains as perhaps one of its most significant accomplishments. The Paris Convention, adopted by the OEEC Council on July 29, 1960, is the first of several international instruments that establish clear rules of responsibility and levels of compensation for damage caused by nuclear activities to ensure equitable treatment in all countries. Other international treaties and amendments over the years have broadened the applicability and updated the compensation levels. It should be noted that the United States is not a party to any of these conventions. The 1957 Price-Anderson Amendment to the 1954 Atomic Energy Act, however, confers similar types of protections for incidents in the United States. The foresight displayed by the framers of these early instruments in addressing issues of nuclear liability in advance of any incident potentially requiring compensation is still considered remarkable.

The second of these committees, now the Committee on Radiation Protection and Public Health (CRPPH), was initially established by the Steering Committee as a working party in March 1957. In February 1958, this became the Health and Safety Committee (HSC), and in 1973, it finally took its current name. Since radiation pro-

NEA Timeline: The First 50 Years (1958–2008)

Precursors

1948	16 April	• Organization of European Economic Cooperation (OEEC) established
1953	14 December	• Secretary-general submits report to OEEC Council of Ministers on energy supply difficulties
1954	December	• United Nations conference on peaceful uses of atomic energy held
1955	May	• Report by Louis Armand citing potential of nuclear energy and need for European cooperation
	10 June	• Working Party on Nuclear Energy set up
	15 December	• Working Party submits its report
1956	29 February	• Council of Ministers establishes Special Committee on Nuclear Energy; four working parties develop proposals
	March	• Prof. Leander Nicolaidis, of Greece, appointed chair of Special Committee on Nuclear Energy
	18 July	• Council of Ministers responds to working parties' proposals with a series of actions, including the establishment of a Steering Committee for Nuclear Energy (SCNE)
	November	• Prof. Leander Nicolaidis appointed chair of SCNE
1957	24 January	• Working Group on Harmonization of Legislation established to examine third party liability for damage caused by the peaceful use of nuclear energy (11 members of OEEC join)
	21 March	• Working Party on Public Health and Safety established by SCNE
	3 July	• Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy established by SCNE, replacing former Working Group (first meeting held 22 January, 1958)
	29 July	• International Atomic Energy Agency established
	20 December	• European Nuclear Energy Agency (ENEA) established by Council of Ministers' decision

The First 50 Years

1958	1 February	• ENEA Statute enters into force (all 17 OEEC members join ENEA); Canada and the United States are associate members; Pierre Huet, of France, appointed director-general
	21 February	• Health and Safety Committee (HSC) established • Halden Reactor Project established
1959		
1960	29 July	• Paris Convention on Third Party Liability in the Field of Nuclear Energy adopted by OEEC Council • Agreement for cooperation signed between ENEA and IAEA
	14 December	• Convention establishing the Organization for Economic Cooperation and Development (OECD) signed in Paris, France
1961		• OEEC becomes OECD
	Autumn	• Prof. J. M. Otero y de Navascues, of Spain, elected chair of SCNE
1962		
1963	31 January	• Brussels Convention Supplementary to the Paris Convention adopted
1964		• Einar Saeland, of Norway, appointed director-general
	July	• Prof. U. W. Hochstrasser, of Switzerland, elected chair of SCNE • ENEA common services created (Computer Program Library at Ispra, Italy, and Neutron Data Compilation Center at Saclay, France • Study Group on Long-Term Role of Nuclear Energy (NELT) established
1965		• Japan joins ENEA as associate member • Committee on Reactor Safety Technology (CREST) established
1966		
1967	June	• H. H. Koch, of Denmark, elected chair of SCNE
1968		
1969	April	• Prof. Carlo Salvetti, of Italy, elected chair of SCNE
1970		
1971		
1972		• Japan becomes a member
	20 April	• Name changed from ENEA to Nuclear Energy Agency (NEA)
	May	• Reinhard Loosch, of Germany, elected chair of SCNE
1973		• Australia becomes a member • Committee on Radiation Protection and Public Health (CRPPH) established, replacing HSC
		• Committee on Safety of Nuclear Installations (CSNI) established, replacing CREST and taking on the regulatory functions of HSC

tection affects all uses of the atom, not just power production, the CRPPH and its predecessors have always enjoyed broad participation among the NEA's member countries.

The initial mandate of the HSC was to develop recommendations for radiation protection that member countries could apply in their own national legislation. In doing so, the forerunners of the CRPPH worked closely with the International Commission on Radiological Protection. That relationship continues to this day. One of the earliest achievements of the CRPPH was the publication in 1959 of its Radiation Protection Norms, which helped establish the measures member countries could take to ensure adequate protection against the hazards of ionizing radiation. The norms, which had an enduring impact, were replaced in 1981 by *Basic Safety Standards for Radiation Protection,* jointly recommended by the OECD/NEA, the IAEA, the International Labor Organization, and the World Health Organization and published by the IAEA in 1983 as No. 9 in its Safety Series.

Other activities quickly followed the formation of the ENEA, including some that do not survive today. One other enduring project, however, is worth mentioning. The same year that the ENEA was established, the Halden Reactor Project in Norway was launched. It quickly became the prototype for many other joint research projects for which the ENEA staff, and later, the NEA staff, served as a technical secretariat. The Halden Reactor Project has evolved over the years and is still an ongoing project. Its international collaboration is still coordinated by the NEA, and it remains the NEA's largest joint research project. Of equal importance, a number of other joint

1974		
1975		• Canada becomes a member • Radioactive Waste Management Committee established
1976		• Finland and the United States become members
	April	• Dr. Bo Aler, of Sweden, elected chair of SCNE
1977		• I. Williams, of the United Kingdom, appointed director-general • Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) established, replacing NELT
1978		• Data Bank established in Saclay, France
1979	April	• Hiroshi Murata, of Japan, elected chair of SCNE
1980		• Incident Reporting System (IRS) established by CSNI for the exchange of information on incidents in reactor operations
1981		
1982		• Howard Shapar, of the United States, appointed director-general
	April	• Ivor Manley, of the United Kingdom, elected chair of SCNE
1983		
1984		• Joint NEA/IAEA Uranium Group established
1985	April	• Ambassador Richard Kennedy, of the United States, elected chair of SCNE
1986		
1987	March	• Report titled *The Radiological Impact of the Chernobyl Accident in OECD Countries* published
1988		• Kunehiko Uematsu, of Japan, appointed director-general
1989		• Committee on Nuclear Regulatory Activities (CNRA) established, splitting off regulatory activities from CSNI
1990		• International Nuclear Event Scale (INES) established by NEA and IAEA to standardize reporting of nuclear incidents and accidents to the public
1991		• Nuclear Science Committee (NSC) established
	April	• Dr. Robert Morrisson, of Canada, elected chair of SCNE
	18 November	• Information System on Occupational Exposure (ISOE) established
1992		
1993		• Fuel Incident Notification and Analysis System (FINAS) created • First International Nuclear Emergency Exercise (INEX) conducted
1994		• South Korea and Mexico become members • NEA moves from boulevard Suchet to Issy-les-Moulineaux
	October	• Dr. Jorg Hermann Gosele, of Germany, elected chair of SCNE
1995		• Sam Thompson, of the United States, becomes acting director-general
1996		• Czech Republic and Hungary become members
	October	• Christian Prettre, of France, elected chair of SCNE
1997		• Luis Echávarri, of Spain, appointed director-general • High-level advisory group established by secretary-general to review NEA
1998		• Report of the high-level advisory group completed
	October	• Lars Hogberg, of Sweden, elected chair of SCNE
1999		• First NEA Strategic Plan published
2000	12 October	• Nuclear Law Committee (NLC) established, replacing Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy
2001		• NEA, IAEA, and World Association of Nuclear Operators agree to develop joint Nuclear Events Web-based System (NEWS) to transmit information on nuclear incidents
	Aug/Sept	• International School of Nuclear Law (ISNL) established jointly with the University of Montpellier I, Montpellier, France
2002	13 June	• Slovak Republic becomes a member
2003	October	• William Magwood, of the United States, elected chair of SCNE
2004		• NEA becomes technical secretariat for the Generation IV International Forum (GIF)
2005		• First NEA Safety and Regulation Forum conducted
	April	• Jussi Manninen, of Finland, elected acting chair of SCNE
	October	• Jussi Manninen elected chair of SCNE
2006		• NEA becomes technical secretariat for Stage 2 of the Multinational Design Evaluation Program (MDEP)
	April	• Richard Stratford, of the United States, elected chair of SCNE
2007		• Agreement for cooperation with Russia signed
2008	1 February	• 50th Anniversary of NEA

projects have been conducted over the years. Many have been completed, but there are currently about 20 active joint projects, the majority of them focusing on safety-related research. It is noteworthy that these projects included countries that were not ENEA members.

During the first decade or so of the ENEA's existence, the scope of its work continued to expand. The important work in the areas of nuclear liability law, radiation protection, and research continued, but new programs were started as needs were identified by member countries through the Steering Committee. The coordination of nuclear data compilation was initiated in 1964 with the creation of the Neutron Data Compilation Center at Saclay, France. In 1978, the activities of this group and the Computer Program Library in Ispra, Italy, were merged to create the NEA Data Bank, which still exists today. The 1960s also saw the initiation of efforts to look at broader issues of nuclear energy development and to address reactor safety issues. The study group on the long-term role of nuclear energy was started in 1964, and the Committee on Reactor Safety Technology in 1965. Both committees would evolve further in the 1970s.

Evolution to the NEA

In 1972, Japan became the first country outside of Western Europe to join the ENEA. Japan had previously been a participant in the early data bank activities and had joined the United States and Canada as an associate member of the ENEA in 1965.

Although in general, membership in the NEA has followed accession to the OECD, it is not a requirement that the country be an OECD member first.

As a result of Japan's membership, "European" was dropped from the agency's name, and it became the Nuclear Energy Agency. Close on the heels of Japan's accession, Australia joined the NEA in 1973, Canada in 1975, and Finland and the United States in 1976. Later, South Korea (1993), Mexico (1994), Hungary and the Czech Republic (1996), and the Slovak Republic (2002) would join.

Although in general, membership in the NEA has followed accession to the OECD, it is not a requirement that the country be an OECD member first. In the case of South Korea, membership in the NEA (1993) actually preceded its membership in the OECD (1996). It is unusual, however, for an NEA member not to be an OECD member; Korea is the only country to date where this has occurred, and at the time that NEA membership was offered, it was expected that Korea would soon thereafter become a member of the OECD.

As the membership of the NEA expanded, so too did its activities. In response to emerging needs, it established a number of activities and products that remain important today. Among them are the following:

- The Incident Reporting System, established by the NEA's Committee on the Safety of Nuclear Installations in 1980 for the exchange of information on incidents in reactor operations, now operated jointly with the IAEA.
- The Joint IAEA/NEA Uranium Group, established in 1984 to produce a periodic report on uranium resources, production, and demand, commonly known as the "Red Book" because of the color of its cover.
- A series of peer reviews of national radioactive waste disposal programs, conducted for member countries upon their request and with their support.
- The International Nuclear Event Scale, established in 1990 to standardize reporting to the public on nuclear incidents and accidents, now operated by the IAEA.
- The Information System on Occupational Exposure, established in the early 1990s and jointly sponsored with the IAEA.
- The Fuel Incident Notification and Analysis System, created in 1993 and operated jointly with the IAEA.
- The International Nuclear Emergency Exercise series, the first of which was conducted in 1993.
- The Nuclear Events Web-based System, to transmit information on nuclear incidents, initiated jointly by the NEA, the IAEA, and the World Association of Nuclear Operators in 2001.
- The International School of Nuclear Law, established jointly with the University of Montpellier I, Montpellier, France, in the summer of 2001.

It is particularly noteworthy that several of these activities were either initiated jointly with the IAEA, or have been passed on to the IAEA to serve the needs of its much larger membership (currently 144 countries). These collaborative efforts reflect the close working relationship between the two agencies and the ways that NEA activities, piloted within a small, more agile group of advanced countries, can later be expanded to serve the needs of a larger and more diverse group of countries.

The NEA has produced numerous studies, reports, and workshops over the years in response to specific events or needs covering a wide range of topics of interest to the NEA's member countries.

In addition to these activities, all of which are ongoing or are periodically repeated, the NEA has produced numerous studies, reports, and workshops over the years in response to specific events or needs covering a wide range of topics of interest to the NEA's member countries. Several of them have been circulated widely and have become classics in their field. Perhaps one of the most prominent examples is the NEA report, *The Radiological Impact of the Chernobyl Accident in OECD Countries,* published in March 1987. Many other NEA products have also contributed to the understanding of nuclear technology and to nuclear policy development around the globe.

The 1970s also saw the evolution of the standing committee structure to that which exists in the NEA today. In addition to some of the name changes and reorganizations of functions previously noted, other changes were made to better reflect not only the work being done, but also the expertise needed from the member countries for each activity. Thus, the reactor safety effort was broadened to reflect all types of nuclear installations, and still later, the regulatory activities were split off. A committee was formed to specifically address the waste management area, and another committee was established to cover scientific studies.

The NEA today

The NEA today has 28 member countries and a staff of about 70 people. (Two OECD members, Poland and New Zealand, are not members of the NEA.) Its seven standing technical committees operate under the direction of the Steering Committee, which in turn reports to the OECD Council, to

carry out the program of work of the agency, assisted by the NEA staff. These seven committees are:

- Committee on the Safety of Nuclear Installations.
- Committee on Nuclear Regulatory Activities.
- Radioactive Waste Management Committee.
- Committee on Radiation Protection and Public Health.
- Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle, known as the Nuclear Development Committee.
- Nuclear Law Committee.
- Nuclear Science Committee.

Some of the committees have a number of standing and temporary subgroups under them. The former address various broad and long-term areas of the committee's mandate, while the latter are instituted from time to time to conduct specific, shorter-term tasks.

In addition, the NEA operates a data bank that serves as an international reference center for its member countries for basic nuclear tools, such as computer codes and nuclear data, used in the analysis and prediction of phenomena in the nuclear field. It also develops and validates these tools for its members as requested. The data bank has separate membership and funding. Twenty-two of the 28 NEA members are also members of the data bank. The United States, which has its own organization—the Radiation Safety Information Computational Center at Oak Ridge National Laboratory—to perform similar functions, is not a member of the data bank but does cooperate closely with it. In the mid-1990s, the NEA moved from its location near OECD headquarters in Paris, France, to its current location in Issy-les-Moulineaux, just outside Paris. The move allowed the consolidation of the operations of the data bank, which had been at Saclay, France, an outer suburb of Paris, with the rest of the agency.

The NEA operates a data bank that serves as an international reference center for its member countries for basic nuclear tools, such as computer codes and nuclear data.

Experts from the member countries are appointed by their governments to serve on NEA committees, as well as on the specialized working groups and expert groups established by the committees to carry out certain tasks. While the NEA's staff is very small, about 3600 people a year participate on NEA committees and their constituent subgroups, and in its workshops and studies. This expanded circle of experts allows the NEA to produce 60–70 publications a year, in addition to holding numerous meetings and workshops.

While the NEA's staff is very small, about 3600 people a year participate on NEA committees and their constituent subgroups, and in its workshops and studies.

In addition to its program of work, which is funded from the regular budget of the agency and, therefore, by all its members, the NEA also occasionally undertakes specialized activities for countries that provide additional funds. Such work must be compatible with its basic mission and must be approved by the Steering Committee. Past and current activities include the joint projects that have been conducted over the years, special peer reviews of waste sites in several countries, and, most recently, service as the technical secretariat for the Generation IV International Forum (GIF) and for Stage 2 of the Multinational Design Evaluation Program (MDEP), two important international initiatives started in recent years.

Future directions for the NEA

After a successful first half-century, the NEA is poised to build upon its successes in the years ahead. It has a well-established and successful *modus operandi* and enjoys an excellent reputation for the quality of its studies and the effectiveness of its work.

One of the big concerns about the NEA has been that its membership does not include several countries with significant and growing nuclear power programs and active nuclear research efforts, namely Russia, China, and India. In fact, OECD and NEA policy provides a mechanism for nonmember countries, and even on occasion nongovernmental organizations, to participate in the work of their committees as observers. The word "observer" is a bit of a misnomer because the only countries and organizations invited to serve in this capacity are ones that are expected to be actively involved in the work of the committee. The NEA has had such participation on a number of its committees for many years. Russia, in particular, has participated actively in several NEA committees, and a March 2007 agreement between the NEA and the Russian Federation seeks to expand the involvement of Russian experts to all NEA committees.

The relationship with China is newer, and at present, more limited, but the NEA is currently trying to expand its interactions with China. The expectations are that the mutual value of Chinese participation in NEA activities will increase as China's nuclear power programs grow and as it becomes more of a force in the international nuclear marketplace. The initial focus is on Chinese participation in some of the safety-related activities of the NEA. China is already a member of the MDEP, for which the NEA is the technical secretariat.

The NEA presently does not have a formal relationship with India. This lack of involvement is a reflection of the policies of several of its member countries, including the United States, because India is not a signatory to the Non-Proliferation Treaty. India has not participated in any NEA committees or other activities. At this writing, however, the United States is engaged in an effort to develop an agreement for its own cooperation with India. Should that happen, together with related actions being requested of the Nuclear Suppliers' Group, it is likely that the NEA member countries would be amenable to NEA cooperation with India. At that time, the NEA would likely seek to involve India in some of its committees and other activities.

Another potential development facing the NEA in the future is the possibility of an expanded membership. On May 21, 2007, the OECD announced its intention to open membership negotiations with Chile, Estonia, Israel, Russia, and Slovenia. In addition, the OECD will offer enhanced engagement with a prospect of membership to Brazil, India, Indonesia, China, and South Africa. Finally, candidates for the future enlargement of the OECD include the remaining EU members: Bulgaria, Cyprus, Latvia, Lithuania, Malta, and Romania. If these countries

become a part of the OECD family, some of them—particularly those that already operate nuclear power plants or that have active plans to do so—will undoubtedly wish to join the NEA as well.

Although concerns about the duplication of efforts between the NEA and the IAEA have been raised periodically over the years, a consensus seems to have emerged that the two organizations have separate but related roles. The two organizations have had formal cooperative agreements for most of their existence. Over the years, they have developed strong and mostly positive cooperative relationships, which include the conduct of a number of joint reports and joint workshops. One well-known example is the Uranium "Red Book," which has been produced periodically as a joint effort for a number of years. Nevertheless, the two agencies must continue to coordinate closely, because the strong overlap of their interests can easily lead to duplication if not closely monitored at the management level.

Substantively, the focus of the NEA's work is not likely to change dramatically in the coming years. The agency has a well-established, well-respected program in a selected number of key areas and a budget that has remained fairly flat in recent years. Therefore, work is likely to continue to focus on those areas. Nevertheless, the work does continue to evolve in a planned and structured way, guided by a strategic plan that covers five-year periods. The practice of developing strategic plans was started in the late 1990s, as a result of a report on the agency produced in 1998 by a high-level advisory group established by the OECD secretary-general the preceding year. The agency is now in the middle of its second five-year strategic plan, covering the period 2004–2009.

Throughout its history, one of the hallmarks of the NEA has been its ability to respond to changing situations. Its small size and small membership has facilitated that, and it has therefore been able to be responsive to new developments and situations. One example is the Chernobyl study mentioned earlier.

Finally, the ability of the NEA to undertake special projects funded outside the regular budget gives it a great deal of flexibility to respond quickly to emerging developments and new needs. In that regard, the role it has recently taken as technical secretariat for two relatively new international initiatives, GIF and MDEP, ensure that it is working on the forefront of two key areas—advanced nuclear reactor development and international cooperative efforts on licensing. These two areas will be important in the coming years, particularly if projections of growth in the use of nuclear power materialize. The NEA's participation in these initiatives could lead to further work for the agency in these areas, either as part of the continuing efforts of GIF and MDEP, or in the form of other related activities that could be identified as a result of the GIF and MDEP efforts, and that some countries may wish to support through supplementary funding.

Looking back and ahead

The NEA's first 50 years has spanned most of the history of nuclear power, and its activities have covered a wide range of issues and areas of interest to its member countries. Its reports and contributions are highly respected worldwide, and it has developed excellent working arrangements with other international intergovernmental organizations, several key countries outside its membership, and major international nongovernmental organizations. As it begins its second half-century of activity, it is poised to continue to make important contributions to the international nuclear community and to the governments of its member countries. The NEA's workshops and reports will continue to aid its member countries, as well as other countries, in their efforts to ensure the safe operation of their nuclear facilities, to address long-term issues such as waste disposal, and to make other important policy decisions relating to nuclear applications. NN