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Towards the European Nuclear Engineering Education Network

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ABSTRACT

Current priorities of the scientific community regarding basic research lie elsewhere than in nuclear sciences. The situation today is significantly different than it was three to four decades ago when much of the present competence base in nuclear sciences was in fact generated. In addition, many of the highly competent engineers and scientists, who helped create the present nuclear industry, and its regulatory structure, are approaching retirement.

To preserve nuclear knowledge and expertise through the higher nuclear engineering education in the 5th framework program of the European Commission the project ENEN (European Nuclear Engineering Education Network) was launched, since the need to keep the university curricula in nuclear sciences and technology alive has been clearly recognized at European level.

As the follow up of this project an international nuclear engineering education consortium of universities with partners from the nuclear sector is presently in process of being established This association called ENEN has as founding members: 14 universities and 8 research institutes from 17 European countries.

1 INTRODUCTION

At present time nuclear power plants provide roughly 30% of the total electricity actually consumed in the European Union and in the Candidate States. In addition, it will be in the short and in the longer-term perspective difficult to meet the Kyoto targets regarding the significant reduction in release of greenhouse gases like CO_2 into the atmosphere without, at least, keeping the production of nuclear electricity at its present level. Also on the global

scale, there is no sign of decreasing demand in the medium to longer-term perspective for electricity as a form of convenient high quality energy.

Although the nuclear power industry is not in a development phase, nuclear companies continue to make major investments in their existing plants to ensure that they comply with modern safety and operational requirements. There are indications of major efforts in designing the next generation systems for the upturn in the industry, which many expect to come as the main response to meet the challenge of global warming. However, until this comes about, the nuclear power industry must continue to maintain the efficient and safe operation of existing plants and when operation ceases undertake their safe decommissioning. This in turn means that irrespective of any plans to build new plants, both the industry and its regulator will require a high level of nuclear competence for many decades to come [1].

With no new-build programme the scope to maintain technical competencies and moreover attract the right calibre of new recruits into the industry becomes a difficult task. Decline in interest for nuclear education courses throughout the European Union has been noted and has become a major concern. The demography of those working in the industry research and academia indicates that given the ageing workforce profile there is the danger of competence being initially eroded and ultimately lost. One indicator for this is that in Europe the number of self-standing nuclear energy undergraduate programs seem to be decreasing significantly. Over the years they have become subprograms or electives inside other disciplines, e.g. engineering, physics or similar. Studies funded by the European Commission (SOFRES [2]) and by the OECD/NEA [3] confirmed that a problem exists and needs addressing.

In the field of scientific and technical knowledge, similarly to what happens in the field of safety, keeping a given level can only be obtained by continuing efforts to make progress. Knowledge frozen in books or saved on magnetic media is knowledge subject to ageing.

To preserve nuclear knowledge and expertise through the preservation of higher nuclear engineering education in the 5th framework program of the European Commission the project ENEN (European Nuclear Engineering Education Network) was launched. With this project the European Commission financially and morally supports the efforts aimed at nuclear education and training, and she is willing to pursue this action within each of the large research projects of the 6th framework programme.

As the Commission is not in charge of the organisation of the higher education in Europe, its assistance cannot be used for direct funding of teaching. Consequently, the persons in charge of local curricula in nuclear sciences and technology must continue to convince their own institutions to maintain the indispensable basic courses, and at the same time, they have to establish international cooperation to develop even more attractive and higher quality curricula.

2 EUROPEAN NUCLEAR ENGINEERING EDUCATION NETWORK PROJECT

The objective of the ENEN project is to propose a global strategy, defining the major elements for a European network for nuclear engineering education, and to perform pilot sessions on European nuclear education. The concerted action is a step towards farther-reaching objectives, that is the conservation and management of the nuclear knowledge and expertise, the creation of a European higher education space as part of the European Research Area and the integration of "New Joiners" in the EU.

In the ENEN Project 14 universities and 8 research institutes from 17 European countries are participating (Table 1). Through co-operation between universities and universities and research centres, better use will be made of dwindling teaching capacity,

scientific equipment and research infrastructure. The duration of the project is 24 months from January 1, 2002 till December 31, 2003. The work is broken-down in 11 work packages. The matrix of different contractors participating in several work packages, acting in cases as work package leaders and in others as contractors, gives a broad basis to the project, creates transparency and guarantees consistency. The project covers different aspects, in fact generic, for a higher education network, among others: state of the art; prerequisites to enter the education; education curricula, continuing education; teachers qualification; student and teachers mobility; identifying the most adequate organisations to perform the education and training; teaching practice, distant learning, Euro-courses; co-operation with research institutes that operate larger nuclear infrastructures; keep a finger on the pulse of industry etc. The work itself consists mainly in gathering and digesting information, formulating proposals for a global strategy, performing pilot education sessions and producing a clear roadmap for the way ahead in nuclear engineering education in Europe.

Table 1: ENEN participating institutions

Institution	Country
SCK•CEN	Belgium
Budapest University of Technology and Economics	Hungary
Czech Technical University	Czech Republic
Jožef Stefan Institute	Slovenia
CEA-INSTN	France
Kungl Tekniska Högskolan	Sweden
K.U.Leuven Research and Development	Belgium
Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare	Italy
Universiteit Gent	Belgium
Slovak University of Technology	Slovak Republic
Swiss Federal Institute of Technology Zürich	Swiss
Delft University of Technology	Netherlands
Helsinki University of Technology	Finland
Atominstitut der Österreichischen Universitäten	Austria
Université Catholique de Louvain	Belgium
University of Birmingham	United Kingdom
University "Polithenica" of Bucharest	Romania
Universidad Politecnica de Madrid	Spain
National Technical University of Athens	Greece
Technische Universität München	Germany
Ustav jaderného vyzkumu REZ	Czech Republic
Center of Technology and Engineering for Nuclear Projects	Romania

To demonstrate the benefits of the international cooperation in nuclear education a pilot session in nuclear education was organized from April 28 to May 16, 2003. A group of four university institutions (SUT Bratislava, CTU Prague, BUTE Budapest, AÖU Vienna) managed to merge together one of their existing courses into the three weeks “Eugene Wigner” Training Course for Reactor Physics Experiments, which was accepted by all ENEN universities as being an integral part of their national curriculum, worth 8 European Credit Transfer System (ECTS) points. The main emphasis of the course was to perform reactor physics experiments on three different research and training reactors in three different cities (Vienna, Prague, Budapest). Before the experimental work theoretical lectures were held in

Bratislava to prepare the students for the experiments. In total 21 students, originating from 10 countries, structured in 4 groups, which moved around the different locations, participated at the course.

SCK•CEN Mol under the coordination of BNEN (Belgian Nuclear Education Network) will organize the next pilot sessions in the field of Nuclear Thermo-Hydraulics and Nuclear Reactor Theory in October and November 2003. Both courses will last two weeks.

3 EUROPEAN MASTER OF SCIENCE DEGREE IN NUCLEAR ENGINEERING

One of the important tasks of the ENEN Project is to develop a flexible and efficient curriculum for the European Master of Science Degree in Nuclear Engineering (EMNE). The curriculum must take into account the following facts:

- Nuclear science and engineering covers different professional disciplines.
- Currently there are noticeable differences in educational systems within the EU.
- The program must assure optimal use of available resources in Europe.

The curriculum shall therefore enable each individual post-graduate student to obtain high quality education tailored to her/his goals, needs and wishes, using potential and educational resources available at the European level as a whole.

The European master of science degree program in nuclear engineering (EMNE) is intended for candidates that have completed their study at the graduate level (BSc) or hold a university diploma (of a study that has lasted at least 4 years) in any of the following disciplines: mechanical engineering, chemical engineering, electrical engineering, physics, control engineering, energy engineering and others. Fig.1 presents the general architecture of EMNE, which takes into account that there are currently different possibilities to get the degree. At this time the dependence of the curriculum on the entrance level of the students should help further harmonization efforts.

To reach the masters degree the candidate should normally accumulate in total 300 ECTS, where each academic year accounts for 60 ECTS. As a consequence it will take 5 years to receive the European Master of Science Degree in Nuclear Engineering when the Bologna Convention will be fully accepted and operational. Until then it is essential to assure a viable path for each student that received his first degree (BSc, Diploma, Laurea) to follow the nuclear engineering program to earn his European nuclear masters degree. In the EU there are currently engineering degrees after following three, four or five years graduate programmes. Only a very few universities offer graduate degrees in nuclear engineering. Some universities offer courses in nuclear engineering at some engineering programmes at the graduate level. The majority of universities and their departments on the other hand do not cover nuclear subjects at all.

To compensate these differences the scheme presented on Table 2 is proposed. The essence of the EMNE are 60 ECTS that are composed of: 24-36 ECTS nuclear core preferred and substitute courses, 6-12 ECTS nuclear core laboratory preferred and substitute courses, 12-18 ECTS elective advanced and specialized nuclear courses and the thesis, which is worth 12-24 ECTS. This as a minimum has to be collected by each student wishing to be awarded the EMNE degree regardless of his previous educational background.

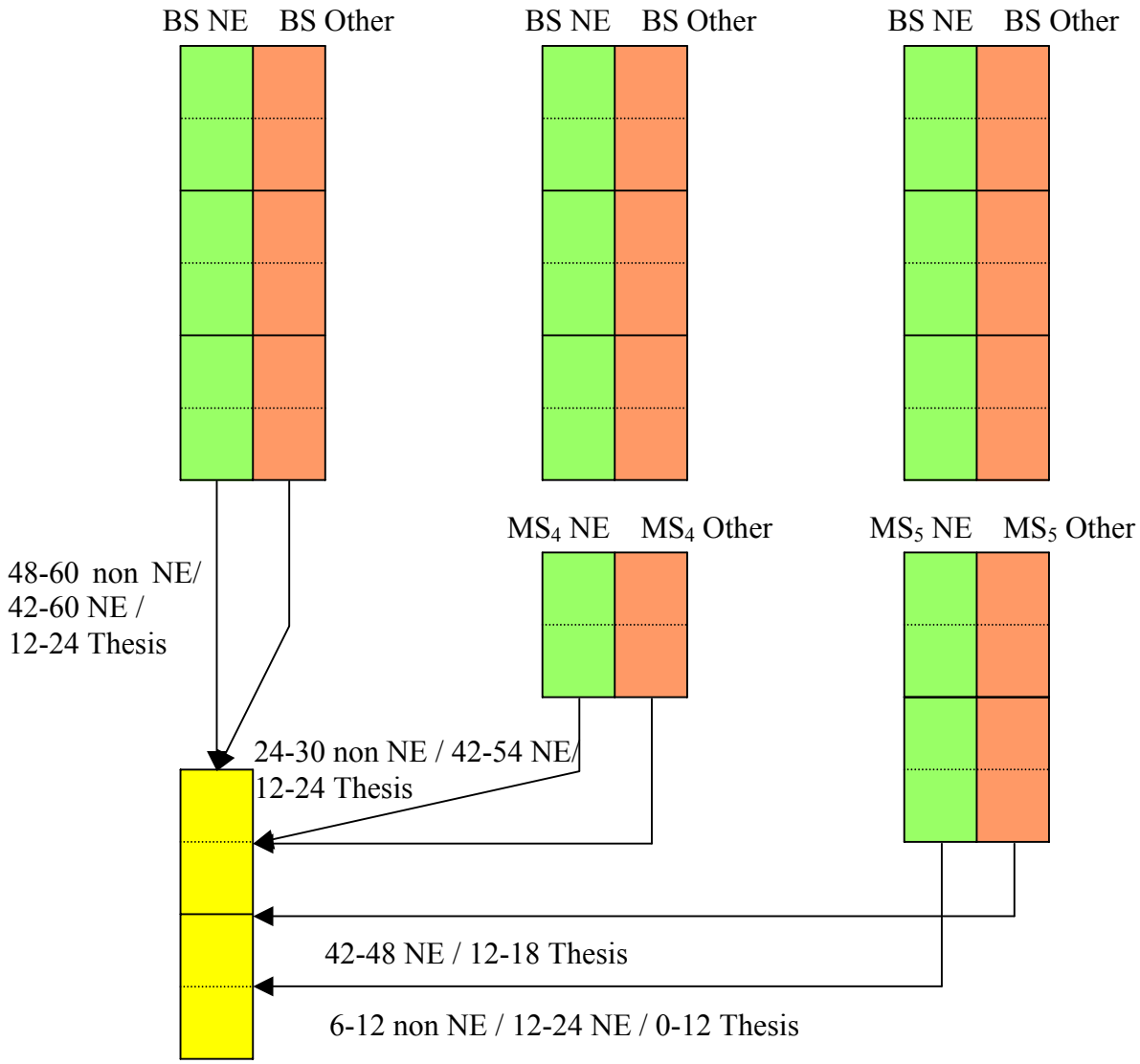

Figure 1: European Master of Science Degree in Nuclear Engineering architecture.

The purpose of the remaining basic and advanced non-nuclear courses (engineering, physics, mathematics, etc…) is to balance the different levels or areas of knowledge the students have after (completing 3, 4 or 5 years engineering study) receiving their first diploma. The selection of these non-nuclear courses should normally be made for each student individually with the assistance of his mentor or supervisor. Students, who may have already passed some of the preferred nuclear core courses during their undergraduate study, shall replace them with substitute nuclear core courses.

Students holding a degree (BSc) awarded to them **after three academic years** (180 ECTS) of education should during their first year enrol into basic (24-30 ECTS) and advanced (24-30 ECTS) non-nuclear courses. Students finishing **four academic years** (240 ECTS) for their first degree (diploma) should during their first year enrol into advanced (24-30 ECTS) non nuclear courses before continuing with the 60 ECTS essence part of EMNE. Students completing **five academic years** for their non-nuclear engineering degree will need only the essence 60 ECTS to complete EMNE. Students, who finished a 5 years (300 ECTS) nuclear engineering undergraduate program will need 30 ECTS to complete EMNE, that means 6-12 ECTS advanced non nuclear courses, 6-12 ECTS nuclear core laboratory courses and 6-12

ECTS elective advanced nuclear courses. The EMNE thesis work (12 ECTS) has only to be done if the undergraduate thesis has not been done in the nuclear field.

Table 2: European Master of Science Degree in Nuclear Engineering scheme.

	Undergraduate Engineering Study (years)	ENG 3y	ENG 4y	ENG 5y	ENG 5y***
	Engineering (nuclear / non nuclear)	any	any	non nuclear	nuclear
	Years to complete (typically)	3	4	5	5
	ECTS accumulated to complete	180	240	300	300
	EMNE	ECTS	ECTS	ECTS	ECTS
1	non nuclear basic (24-30 ECTS)	6	0	0	0
2		6	0	0	0
3		6	0	0	0
4		6	0	0	0
5			0	0	0
6	non nuclear advanced (24-30 ECTS)	6	6	0	6
7		6	6	0	0
8		6	6	0	0
9		6	6	0	0
10				0	0
1	nuclear core - preferred/substitute (24-36 ECTS)	6	6	6	0
2		6	6	6	0
3		6	6	6	0
4		6	6	6	0
5					0
6					0
7	nuclear core laboratory - pref./subs.(6-12 ECTS)	6	6	6	6
8					
9	nuclear electives - advanced/spec. (12-18 ECTS)	6	6	6	6
10		6	6	6	
11					
1	thesis (12-24ECTS)	12	12	12	0*
	fixed	102	78	54	18
	variable	18	12	6	12
	collected at a partner institution abroad (30 ECTS)	30	30	30	12**
	EMNE ECTS	120	90	60	30
	total ECTS to EMNE	300	330	360	330

0* if the thesis has been done in the nuclear field
12** defined on case by case basis
ENG 5y*** treated separately on case by case basis

An essential condition of the nuclear part of EMNE is that students attend courses, do their seminar work or take exams at least at two universities participating in ENEN. Also acquaintance of the student with different types of (at least training) reactors is desirable. In all cases the program of the students will be finished by the master thesis at nuclear master level. The thesis is a part of the 60 ECTS for the last year nuclear training for EMNE (the thesis is worth 12-24 ECTS), however, it is not inevitable that the thesis work would be finished and defended in the given calendar year. It is well possible that this will require some extra time. This can be adjusted in every case separately, depending on the task and on the skill and progress of the student.

The currently developed EMNE Curriculum takes into account the fact that this educational program is intended for the students that may be later, upon their graduation when they receive the degree, employed by various entities and institutions e.g.: nuclear industry: NPP, A/E, vendors, regulatory authority, universities, research centres, and others, where they may or may not later on receive additional specialized training.

The area that is considered at this time to be the most representative for EMNE, and takes up the majority of courses, is nuclear power. It interfaces other areas that are considered as minor at this time but may be elaborated later e.g. radiation protection, nuclear medicine, nuclear fusion, … The structure and collection of courses will be flexible enough to enable the teachers and the students to fully develop their potentials and fulfil their needs. The syllabus in general will be composed of basic courses (preferred, substitute) to establish a common denominator in basic knowledge of nuclear engineering for all candidates with backgrounds in different disciplines. This structure is being developed together with the list of elective specialized and advanced courses. Currently in partner countries the undergraduate and graduate nuclear engineering educational programs differ in length and level. The lists of preferred and substitute core courses and specialized or advanced courses will have to take into account that at the entry level the program will have to accommodate all graduates wishing to enrol. To harmonize the requirements, the courses will be assigned their ECTS, which will also enable the needed mobility and compatibility. The 120 ECTS EMNE full programs comprise of:

- 4-5 non nuclear basic courses, and 4-5 non nuclear advanced courses,
- 4-6 nuclear core courses and 2-3 nuclear elective courses
- 1-2 nuclear core laboratory courses,

Preferred nuclear core courses	**ECTS**
Introduction to Reactor Engineering	6
Reactor Physics	6
Nuclear Thermal Hydraulics	6
Safety and Reliability of Nuclear Facilities	6
Reactor Engineering Materials	6
Radiology and Radiation Protection	6
Nuclear Reactor Engineering, Laboratory	6

Students, who had passed some of the preferred nuclear core courses during their undergraduate study, will be able to replace them with substitute nuclear core courses.

Substitute core courses	**ECTS**
Nuclear Facilities Environmental Impact	6
Nuclear Fuel Cycle	6
Structural Mechanics - Nuclear	6
Nuclear Power Plant Technology	6
Fluid Mechanics	6
Reactor Control and Instrumentation	6
Nuclear Waste Processing and Disposal	6
Reactor Kinetics	6
Nuclear and Radiation Physics, Laboratory	6
Plant Simulation, Laboratory	6

In addition the master thesis has to be prepared. To assure that the EMNE will really be international at least 30 ECTS have to be collected at an ENEN partner institution abroad where the student has to stay for an agreed time period.

4 EUROPEAN NUCLEAR EDUCATION NETWORK ASSOCIATION

To ensure that education and training provided by ENEN fulfils academic standards and the professional requirements in order to efficiently contribute to maintain adequate competence at national and European levels in an attractive and economic way a new legal entity named ENEN Association is now being established and formally undergoing the registration process.

The ENEN Association shall:

- Deliver a European Master of Science Degree in Nuclear Engineering and promote PhD studies.
- Promote exchange of students and teachers participating in the frame of this network,
- Increase the number of students by providing incentives.
- Establish a framework for mutual recognition.
- Foster and strengthen the relationship with research laboratories and networks, industry and regulatory bodies, by involving them in (or association them with) nuclear academic education and by offering continuous training.
- Organize internal audits on the quality of nuclear engineering curricula.
- Enhance mobility of teachers and students.
- Organize training and advanced courses and promote the usage of large research and teaching facilities or infrastructures.
- Cooperate with international and national governmental institutions, agencies and universities.
- Facilitate the exchange of information on course objectives, content, modes of presentation and other matters.

4.1 ENEN Association Members

There are two types of ENEN association members: Effective Members and Associated Members. The Effective Members are academic institutions or clusters of such institutions having a legal status and meeting all following criteria:

- Provide high-level scientific education in the nuclear field - as full time teaching.
- Provide opportunities for doctorate studies - based on internationally recognized research in nuclear engineering and/or nuclear sciences carried out jointly by the teaching staff, the students, and doctoral and post-doctoral researchers in the same geographic location or in association with a nuclear research centre.
- Use selective admission criteria conforming to legal provisions and/or national practices.
- Be based in the European Union or in one of its candidate member countries.

The Associated Members are corporate bodies having a legal status and meeting the following criteria:

- They are nuclear research centres, government institutions, nuclear companies, regulatory bodies or nuclear learning societies.
- They commit themselves to support the ENEN Association and have a firmly established tradition of relations with some of the members in the fields of education, research and training, and are based in the European Union or in one of its candidate member countries.

4.2 Management of ENEN Association

The organizational structure of the ENEN Association is presented on Fig. 2.

The **General Assembly** is made up of all Effective and Associated Members. Effective Members have one vote per country. The General Assembly has the power to discuss the general policy of the ENEN Association, to take the required measures to implement the decisions, and to establish sub-groups and committees, whenever required.

The **Board of Governors** is made up of six Voting Members and two Associated Members elected by the General Assembly for a period of four years. Each Member of the Board of Governors has one vote and decisions shall be taken upon a simple majority of Members present or represented. In case of equality the President has a double vote. The Board of Governors has the widest powers for the administration and management of the ENEN Association, insofar as these are not reserved for the General Assembly. In particular, the Board is responsible for defining the powers and missions of the General Secretary, establishing sub-committees, drafting their terms of reference, nominating their members, and supervising their activities.

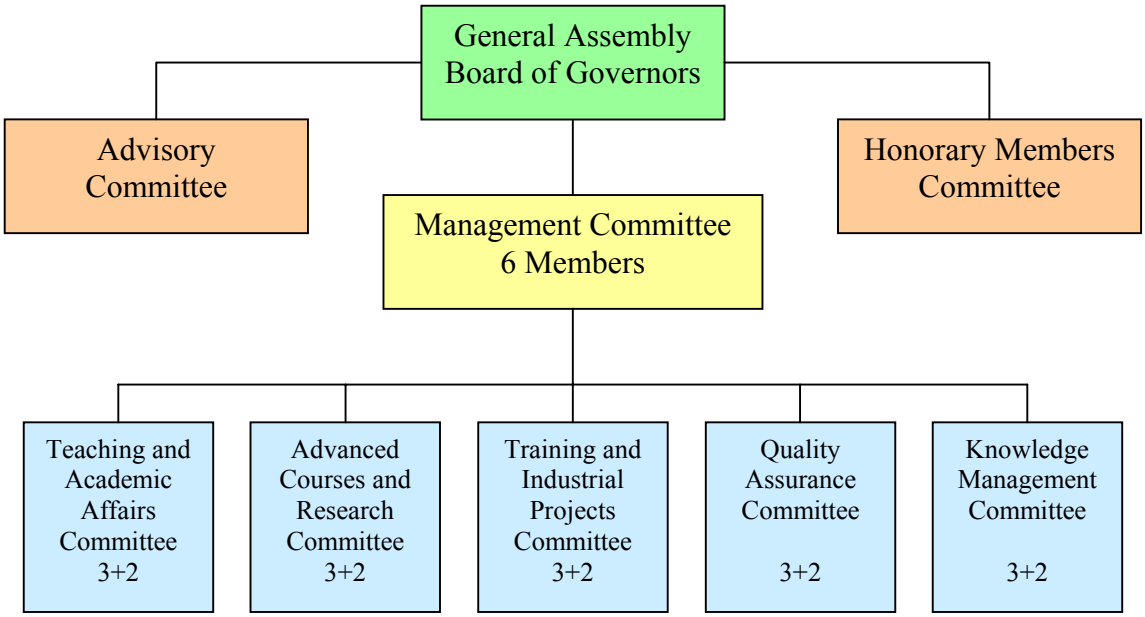

Figure 2: The ENEN Association.

The chairman of each sub-committee and the General Secretary designated by the General Assembly constitute the **Management Committee**. The Management Committee is responsible for the co-ordination of the activities of the sub-committees and for the preparation and implementation of the decisions taken by the Board of Governors. The **Advisory Committee** is the scientific council, constituted by Associated members. Members

of this committee can participate to the meetings organized by the Board of Governors and be consulted on relevant subjects under discussion but with no voting rights. The **honorary members** are designated by the General Assembly. They can be invited to participate to the meetings organized by the Board of Governors and be consulted on relevant subjects under discussion but with no voting rights. The main objective of the **Teaching and Academic Affairs Committee** is the establishment of a clear road map to define the "way" to obtain the European Master of Science Degree in Nuclear Engineering. The main role of the **Advanced Courses and Research Committee** is to ensure the link between ENEN members and research laboratories in the European Community. The **Training and Industrial Projects Committee** is responsible for the integration of European industrial and national projects and it should organize continuous training sessions and courses on different subjects of common interest for the affiliated associated members. The main responsibility of the **Quality Assurance Committee** is to elaborate the quality assurance processes to be applied in the operation of education and training by the institutions members of the ENEN association. The **Knowledge Management Committee** has to identify and monitor deficiencies in scientific knowledge relevant to nuclear technology and safety.

5 CONCLUSIONS

The underlying objective of the ENEN project in the 5th framework program of the European Commission was to safeguard the nuclear knowledge and expertise through the preservation of higher nuclear engineering education. Through co-operation between universities and universities and research centres, better use will be made of dwindling teaching capacity, scientific equipment and research infrastructure. Due to the nature of the project, most participants are from universities, all with nuclear engineering education schemes. The other participants are from research centres, running heavy nuclear infrastructure but also involved in education and training.

In the frame of the ENEN project the basis for the recognized European Master of Science Degree in Nuclear Engineering and the basis for the establishment of the European Nuclear Education Network Association have been set. The organized international pilot session in nuclear education, which experienced great success, demonstrated the benefits of such international cooperation in nuclear education.

Since the establishment of the European Nuclear Engineering Network is so important the work performed in the ENEN project will be carried on also in the 6th framework program of the European Commission in the frame of the extended NEPTUNO (Nuclear European Platform for Training and University Organisations) project.

ACKNOWLEDGMENTS

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