

## Master's degree in Nuclear Engineering UPC-ENDESA. Creating synergy at industrial and academic levels.

L. Batet<sup>1\*</sup>, F. Calviño<sup>1</sup>, M.A. Duch<sup>1</sup>, J. Dies<sup>1</sup>, P. León<sup>2</sup>, P. Fernández-Olano<sup>3</sup>

<sup>1</sup>Universitat Politècnica de Catalunya · BarcelonaTECH

Address: ETSEIB, Av. Diagonal 647, 08028, Barcelona (Spain)

\*Tel: +34 93 401 66 91

\*Email: lluis.batet@upc.edu

<sup>2</sup>ENDESA, Directorate-General for Nuclear Energy

<sup>3</sup>ENDESA, Energy School

**Abstract** – The Master's degree in Nuclear Engineering, born from the alignment of objectives of Academy and Industry, aims to prepare competent engineers to assume managerial positions within the Nuclear Industry. MNE is completely taught in English. Synergies are established at both industrial and academic levels.

MNE syllabus has been designed (and is being continuously improved) with the help of industrial partners and the Spanish Regulatory Body (CSN). One half of the lectures are delivered by professionals external to the university. Besides ENDESA, other companies (ANAV, AREVA, ENRESA, ENSA, ENUSA, IDOM, Nuclenor, Tecnatom, Westinghouse) collaborate in the master. Lecturers from CSN and CIEMAT (the major Spanish research centre) participate in the Master as well. A large portion of the master contents is delivered as Project Based Learning. In general, active learning and team work activities are thoroughly used so as to help the students achieve the learning objectives and acquire a number of soft skills required by industry.

MNE is embedded in EMINE, the European Master in Nuclear Energy (European Institute of Technology, KIC-InnoEnergy). As well, MNE is part of a double degree in the Barcelona Engineering School (ETSEIB) with the official Master in Industrial Engineering (MUEI). Having in the same classroom EMINE and MNE students creates a good working atmosphere, while allowing the future engineers work in a multicultural and international environment. The double degree MNE-MUEI allows students to acquire the MNE competencies and, at the same time, legal engineering attributions. It has been useful to attract good engineering students to the master.

## 1. INTRODUCTION

“Nuclear energy is a key part of the solution in the fight against climate change”, as was declared by the representatives of thirty-nine nuclear societies during ICAPP 2015 [1]. Even though nuclear industry is nowadays stagnant or receding in some European countries, others still see this energy as, if not a cornerstone, an essential part of their energy mix.

According to the International Energy Agency (IEA) forecasts, from 2012 to 2040 the nuclear power global installed capacity will increase by 58% in the New Policies Scenario (119% in 450 Scenario); the amount of nuclear origin electricity produced annually will grow by 88% in the same period and scenario (161% in the 450 Scenario). Asia, Middle East and Russia will lead the growth; the USA will see as well a positive growth of the nuclear capacity in the period covered by the forecast. Following the IEA, the European Union will experience in the this period a reduction of

14% in the installed capacity in the New Policies Scenario and a mild 3% growth in the 450 Scenario [1].

Far from discouraging, this situation, in a globalised economy with an increasing presence of European companies in international projects, will contribute noticeably to a growing need for skilled professionals able to work around the world. It must not be forgotten, moreover, that the ageing of engineering crews working for the operators, service suppliers and regulators in Europe itself will need replacement in the form of qualified engineers, prepared both technically and ethically to assume the responsibilities that working in the nuclear industry requires.

The Master's degree in Nuclear Engineering from BarcelonaTECH (Master UPC-ENDESA) [3] aims to prepare competent engineers to assume managerial positions within the nuclear industry. The master is born from the alignment of objectives of Academy, whose reason of being is the creation and transmission of knowledge, and Industry, needed of professionals able to work rigorously, accordingly to the Safety Culture and imbued of a high sense of responsibility.

Nuclear Engineering education has a history of more than forty years at the Universitat Politècnica de Catalunya (BarcelonaTECH), always linked to the Barcelona Engineering School (ETSEIB).

In 2010, ENDESA approached BarcelonaTECH in order to start defining a future Master in Nuclear Engineering. After several iterations the contents of the master were defined and, early in 2011, the programme was submitted to the National Agency for Quality Assessment and Accreditation of Spain (ANECA) for verification. In March 2011, a Memorandum of Understanding was signed between BarcelonaTECH and ENDESA, by which ENDESA became the principal sponsor of the Master. In October the same year, the first edition of the Master started. In 2015 the Master has been accredited by ANECA. This September the fifth edition has been launched.

Since its beginnings, MNE is embedded in EMINE [4], the European Master in Nuclear Energy (European Institute of Technology [5], KIC InnoEnergy). Part of the academic offer of the MNE is offered as well in the framework of EMINE. The students of this European master choose between BarcelonaTECH and KTH (Sweden) for their first year and then move to France (Grenoble INP or ParisTech) for their second year.

Since 2014, a double degree exists in the Barcelona Engineering School with the official Master in Industrial Engineering (MUEI). In two and a half academic years students can get the double degree MNE-MUEI.

## **2. PARTICIPANTS**

The Master's degree in Nuclear Energy from BarcelonaTECH is a clear exponent of the synergy that can be attained when Industry and Academy cooperate.

ENDESA [6], the main private sponsor of the master, is the largest nuclear plant operator in Spain, holding 47% of the Spanish nuclear capacity. The Master benefits of its long experience and its professional network.

Besides the sponsorship of ENDESA, the Master has the collaboration and in-kind sponsorship of a large part of the Spanish nuclear industry. The list of companies participating in the Master with different degrees of involvement includes: ANAV [7] (the operator of Ascó-1, Ascó-2 and Vandellòs-2 power plants, all of them PWR, in the vicinity of Barcelona), Nuclenor (a company participated by ENDESA that operates a BWR plant in Santa Maria de Garoña), ENUSA [8] (a publicly traded Spanish company for design, manufacture and supply of fuel), ENRESA [9] (a public company in charge of the safe management, storage and disposal of the radioactive wastes

produced in Spain), ENSA [10] (state owned company specialized in the manufacturing of heavy equipment), Tecnatom [11] (advanced engineering), IDOM (engineering company), Initec-Westinghouse and AREVA. The companies participate in different ways, either facilitating that their professionals lecture some specific topics, opening internship positions, or offering guided visits to their facilities.

The list of external participants includes lecturers from CIEMAT (the public major Spanish research centre) [12], who participate mainly in the area of structural materials for nuclear plants and material degradation, but as well in other topics related with the activities of the centre. It also includes professionals from F4E.

Last but not least, the Master has the invaluable collaboration of the Spanish Regulatory Body (Consejo de Seguridad Nuclear, CSN [13]). Technicians from this institution lecture some topics related to Nuclear Safety and Regulations. Moreover, the Argos Chair in Nuclear Safety (in the ETSEIB) sponsored by the CSN, offers scholarships to the students.

Regarding the academic partners, BarcelonaTECH [14] is a public higher education and research institution that specialises in architecture, sciences and engineering, committed to providing high quality technical education. Among its schools, the Barcelona Engineering School (ETSEIB) [15] combines a longstanding tradition (it was established in 1851) with a spirit of renewal and continuous improvement. The School maintains strong ties with the local industrial, financial and social sectors and can boast significant international presence and recognition.

### 3. PROGRAMME ORGANIZATION

The MNE duration is one and a half academic years. Its 90 credits (each credit implies 25 hours of student's work) are divided into one year of courses (60 credits), and one semester of internship plus final project (30 credits). Table 1 gives an overview of the distribution of the credits.

**Table 1. Structure of the MNE programme.**

| Type of Subject         | Credits |
|-------------------------|---------|
| Required courses        | 46.5    |
| Elective courses        | 13.5    |
| Internship              | 15      |
| Master's Diploma Thesis | 15      |
| TOTAL                   | 90      |

The curriculum is organized on the basis of "subject areas". A subject area is understood as a set of contents and training activities aimed at the achievement of certain competencies that can be conceived in an integrated manner. The required subject areas are listed in table 2.

**Table 2. Required subject areas and credits allocated for them.**

| Required Subject Areas   | Credits     |
|--|-------------|
| 1. Fundamentals of Nuclear Engineering and Radiological Protection | 9           |
| 2. Nuclear Power Plants  | 15          |
| 3. Fuel Cycle and Environmental Impact                             | 6           |
| 4. Regulations and Safety  | 6           |
| 5. Management of NPPs  | 10.5        |
| <b>Total</b>   | <b>46.5</b> |

The contents of the different subject areas can be summarized as follows:

- *Fundamentals of Nuclear Engineering and Radiological Protection* includes contents in the areas of Nuclear Physics, Detection and Measurement of Radiation and Radiological Protection.
- *Nuclear Power Plants* is divided into two courses. In one of them, the main *Systems, Components and Materials* of the nuclear and conventional islands of a nuclear power plant are described, with special focus on PWRs. The other course includes contents in the areas of *Reactor Physics and Thermal-hydraulics*.
- *Fuel Cycle and Environmental Impact* includes the description and justification of the different stages of the nuclear fuel cycle, and the quantification of the principal source terms of the environmental impact of a nuclear facility and potential doses.
- *Regulations and Safety*. In this course the Spanish regulatory framework and the basic principles of nuclear safety are described, along with the technologies and procedures developed to meet them.
- *Management of Nuclear Power Plants* includes the operation and maintenance of a nuclear plant, along with design and construction procedures for new plants, the evaluation of costs and the life management.

Since the master aims to prepare qualified professionals, the participation and opinion of the nuclear industry was essential in the definition of the curriculum and syllabus. Besides ENDESA, that played a fundamental role in the definition of the master, active and retired professionals of most of the companies and institutions listed above contributed to shape the master's programme.

## 4. LEARNING METHODOLOGY

MNE is completely taught in English, to attract international students and to train Spanish students to compete in an internationalised labour market.

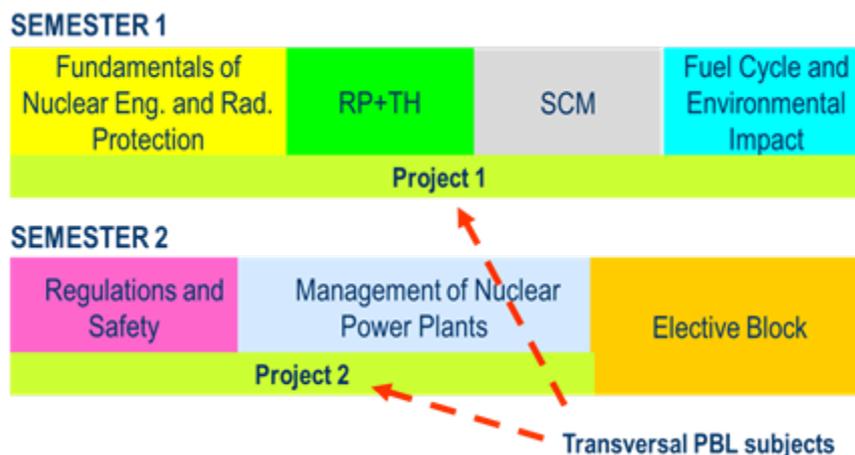
The master is fully adapted to the European Higher Education Area (EHEA) standards, each credit implying 25 h of student work (40% contact, 60% autonomous) including lectures, laboratory activities, use of simulation tools, visits to factories and plants, etc.

To achieve meaningful learning, learners must face realistic situations, similar those encountered in the workplace; they have to apply their knowledge to address problems whose

solution requires making decisions. So, active learning methodologies and team work are used thoroughly in the master.

Assessment is an essential part of the learning process. Evaluation instruments and activities are integrated into the learning activities, are adequate to the complexity of the learning outcome, are diverse and frequent, and are intended to have immediate feedback.

A large portion of the master contents is delivered in a Project Based Learning (PBL) framework, which is very helpful in the education and training of future nuclear engineers. Students, grouped in small teams of 3 or 4 people, develop two transversal course projects (one per semester) involving all the required subjects of the semester (see Figure 1). For instance, in the last editions of the Master the transversal project developed during the second semester has been a 'Feasibility study of plant power up-rating'. PBL techniques are also used, for instance, within the course *Management of Nuclear Power Plants*, where students have been faced with the "Design of a portable system to support the operation in Station Blackout scenarios" (more details of these activities can be found in Reventós et al. [16]). These projects in the second semester are followed up by specialists from industry together with academic staff.



**Figure 1. Sequential distribution of the master's contents during the first academic year**

The master aims to ease students' transition from University to Industry. The industrial internship in the third semester is part of the strategy. Another part is the fact that towards one half of the classes is delivered by lecturers external to BarcelonaTECH (half of them from the industry); this participation is more relevant in subjects of the second semester. Students' visits to industrial facilities complete the strategy.

## 5. SINERGIES WITH INDUSTRY

As has been introduced above, the participation of companies and other institutions in the master does not limit to supply lecturers for specific topics. Industrial partners also offer internship positions that allow the students develop their Master's Final Projects or Theses (see Table 3). Companies contribute this way to the training of the students and, over some months, benefit from the incorporation of young, motivated and skilled workforce.

Guided visits contribute to the students' approach to industrial reality. The list of visits organized with MNE students include one of the ANAV's power plants near Barcelona, the ENUSA's fuel factory in Juzbado, Tecnatom's and ENDESA's headquarters in Madrid, ITER site in Cadarache, the José Cabrera NPP in Guadalajara (being decommissioned by ENRESA), three

days of practices at the full scope simulator of Tecnatom in Vandellòs, the ENRESA's "Centro Tecnológico Mestral" in the site of the decommissioned Vandellòs-I NPP, and the factory of ENSA in Santander.

**Table 3. Summary of students' internships.**

|  | 2013 | 2014 | 2015 | 2016* |
|--|------|------|------|-------|
| Total graduated students                 | 15   | 14   | 10   | 14    |
| EMINE students                           | 9    | 11   | 5    | 7     |
| MNE students in internships:             | 6    | 3    | 5    | 7     |
| ANAV                                     | 3    | 1    | 1    | 1     |
| Westinghouse                             | 1    |      | 1    |       |
| AREVA (Germany)                          | 1    |      |      |       |
| Research centres and Universities abroad | 1    |      |      | 3     |
| BarcelonaTECH (PhD program)              |      | 1    |      |       |
| BarcelonaTECH (diverse projects)         |      |      |      | 2     |
| IDOM                                     |      | 1    |      |       |
| ENDESA                                   |      |      | 1    |       |
| Barcelona Supercomputing Center          |      |      | 1    |       |
| ENUSA                                    |      |      | 1    | 1     |

\* Prevision

Another important activity regarding the adaptation of students to the industry is the participation in the Operating Experiences and Perspectives seminar that every year organizes the Spanish Nuclear Society in Madrid. This seminar represents the students' immersion in the real industrial world. ENDESA sponsors the simultaneous translation of the presentations into English.

As aforementioned, the involvement of Industry and the CSN has been essential in the definition of the master's programme. In fact, the syllabi of the master's courses are being continuously improved with the help of the industrial partners.

The use of active learning, PBL and team work activities over the master help the students not only achieve the learning objectives but also acquire a number of soft skills required by industry. This way the master contributes to prepare future professionals for the nuclear industry.

## 6. ACADEMIC SINERGIES

As has been mentioned, the Master in Nuclear Engineering from BarcelonaTECH is offered as well in the framework of the European Master in Nuclear Energy (EMINE). The program was launched in 2011 by KIC-Innoenergy, the same year as MNE. Electricité de France, AREVA, Vattenfall and ENDESA are industrial partners of EMINE. The Commissariat à l'énergie atomique et aux énergies alternatives (CEA) is as well a Partner of EMINE, along with the Grenoble Ecole de Management.

The inclusion of the MNE within EMINE has been useful to place Universitat Politècnica de Catalunya in the map of the international higher education on nuclear engineering.

In addition to the substantial grants program it offers, KIC InnoEnergy is funding EMINE directly. It allows to develop a series of activities that otherwise wouldn't be possible. Continuous program reviews and improvements are requested by KIC InnoEnergy; it has forced the MNE from BarcelonaTECH to sharpen de saw, and has reinforced the self-demanding attitude of the master's faculty.

In what concerns the daily development of the master, EMINE and MNE students share the same classroom and courses. Having EMINE and MNE students together creates a good working atmosphere, while allowing the future engineers work in a multicultural and international environment. Besides, it somehow forces our Spanish students to use English in more situations than they would have done.

On the other side, EMINE has taken advantage of the MNE. The large industrial involvement in MNE was one of the reasons EMINE received the “EIT label”.

Finally, the double degree MNE-MUEI the ETSEIB offers since 2014 allows students to acquire the MNE competencies and, at the same time, legal engineering attributions. MUEI duration is 120 credits (two years). Taking advantage of common subjects, internship and final project, students can obtain the double degree taking only 171 credits (that can be concentrated in two and a half years). This offer has been useful to attract good engineering students to the MNE.

## 7. FINAL REMARKS AND CONCLUSIONS

The Master’s degree in Nuclear Engineering from the Universitat Politècnica de Catalunya was born with a clear industrial vocation. Students develop a strategic view of the nuclear industry and the ability to comprehend problems and to make decisions, acquire the competencies needed to manage the projects that are run within a company, and cultivate the sense of responsibility which is at the basis of the Safety Culture.

The strengths of the MNE can be summarized as follows:

- Industrial focus of the programme,
- External participation in its definition,
- Learning methodology,
- Longstanding tradition of Nuclear Engineering education in the ETSEIB,
- Large and strong industrial implication in the master,
- Large participation of external expert lecturers,
- Implication of the Spanish Nuclear Regulatory Body (CSN),
- Practical visits to industrial facilities.

Since safety issues are of utmost importance in the exercise of the profession, the existing collaboration between the regulatory authority in Spain (CSN) and BarcelonaTECH concerning nuclear safety is deemed essential for the Nuclear Engineering education.

The connection of master’s faculty with engineers of the industry (active or retired) has been helpful. After years of cooperation in research and technology transfer, and being many of the engineers in ANAV educated at the ETSEIB, the personal links are strong. Senior engineers (former ANAV employees), with years of experience, have helped both in the development and teaching of part of the programme.

BarcelonaTECH is committed to the quality of education; specifically, the MNE’s faculty is highly motivated for continuous improvement. In this line, among other actions, transversal and course projects are being rethought, in line with the requirements of KIC-InnoEnergy [16].

The master must address the competencies and skills the industry requires from a nuclear engineer; and the learning methods must be adapted to these competencies. In this sense a rethought of the competencies addressed by the master is ongoing with the support of the industrial partners.

Finally, it's worthwhile mentioning the willingness of all companies and institutions involved in the MNE to continue cooperating in the program, and especially the will of ENDESA to continue sponsoring it, in a clear commitment to the training of qualified personnel. Nevertheless, BarcelonaTECH is working to increase the industrial presence in the master and to strength the links with the companies involved.

## REFERENCES

- [1] Nuclear for Climate Declaration, Nice (France), 4 May 2015. [http://www.world-nuclear.org/uploadedFiles/org/Features/Climate\\_Change/declaration.pdf](http://www.world-nuclear.org/uploadedFiles/org/Features/Climate_Change/declaration.pdf) (visited on 28 Aug 2015).
- [2] International Energy Agency. *World Energy Outlook 2014*.
- [3] <http://nuclearengineering.masters.upc.edu/>
- [4] <http://www.kic-innoenergy.com/education/master-school/msc-emine-european-master-in-nuclear-energy/> (visited on 28 Aug 2015).
- [5] <http://eit.europa.eu/> (visited on 28 Aug 2015).
- [6] <http://www.endesa.com/en/Home> (visited on 28 Aug 2015).
- [7] <http://www.anav.es/index.php?lang=en> (visited on 28 Aug 2015).
- [8] <http://www.enusa.es/en/> (visited on 28 Aug 2015).
- [9] <http://www.enresa.es/> (visited on 28 Aug 2015).
- [10] <https://www.ensa.es/> (visited on 28 Aug 2015).
- [11] <http://www.tecnatom.es/en/home> (visited on 28 Aug 2015).
- [12] <http://www.ciemat.es/> (visited on 28 Aug 2015).
- [13] <https://www.csn.es/en/home> (visited on 28 Aug 2015).
- [14] <http://www.upc.edu/> (visited on 28 Aug 2015).
- [15] <http://www.etseib.upc.edu/> (visited on 28 Aug 2015).
- [16] F. Reventós, E. Vives, A. Brunet, R.Sabaté, F. Calviño and L. Batet, *Project-Based Learning in the Master's degree in Nuclear Engineering at BarcelonaTECH. Experience gained in the area of Management of Nuclear Power Plants*. 40<sup>th</sup> RA SNE, Valencia, 2014.