30th NENE 2021
September 6 - 9
BLED-SLOVENIA
International Conference Nuclear Energy for New Europe

Strategic Agenda For EU Wide Nuclear Education, Training And Knowledge Management

Leon Cizelj
Jožef Stefan Institute
Jamova cesta 39
1000 Ljubljana, Slovenia
Leon.Cizelj@ijs.si

Csilla Pesznyák
Budapest University of Technology and Economics
Műegyetem rkp 3-9
Budapest 1111, Hungary
csilla.pesznyak@gmail.com

Michèle Coeck
SCK CEN, Belgian Nuclear Research Centre
Boeretang 200
B-2400 MOL, Belgium
michele.coeck@sckcen.be

Jörg Starflinger
University of Stuttgart
IKE
Pfaffenwaldring 31
70569 Stuttgart, Germany
joerg.starflinger@ike.uni-stuttgart.de

Gabriel Lazaro Pavel
ENEN a.i.s.b.l.
Rue d'Egmont 11
1000 Brussels, Belgium
gabriel.pavel@enen.eu

Franck Wastin
European Commission
DG JRC
P.O. Box 2
1755 ZG Petten, Netherlands
Franck.WASTIN@ec.europa.eu

ABSTRACT

The technical, regulatory and market complexities that govern the development, operation, decommissioning, waste management and oversight of nuclear power plants require personnel with outstanding knowledge, skills and motivation. Apart from being technical specialists understanding the installations of increasing technical complexity, the new nuclear talents must be prepared to work in increasingly multidisciplinary, multicultural and highly competitive environments. One would therefore expect that the attraction of new talents followed by the high-class education of nuclear professionals is a thriving activity enjoying strong support by all stakeholders.

An EU wide strategic agenda for nuclear education, training and knowledge management is being developed, partly within the ENEN+ project, to support and consolidate the efforts of the nuclear stakeholders to attract, develop and retain new talents. It considers the projections of needs being developed by the European Human Resources Observatory-Nuclear (EHRO-N) and builds on the existing national nuclear education strategies in EU and beyond and nearly two decades of experience of the European Nuclear Education Network (ENEN).

This paper outlines and substantiates the most important actions required for the EU to retain its leading role in the nuclear power and non-power applications. The sheer complexity of this challenge calls for high level of support, coordination and partnership between all nuclear stakeholders, especially those involved in the decision-making.

1 INTRODUCTION

High quality education and training are vital for any sustainable nuclear energy program. They require universities and training organizations to work together with industry and regulators, as well as with governments in some countries, to ensure the required quality and quantity of the workforce.

The first signs that nuclear higher education might be dwindling were noted and reported in high-level documents [1], [2], [3], [4] at the end of the 20th century. These documents included comprehensive sets of bottom-up and top-down recommendations to preserve and improve nuclear higher education and training.

Many initiatives followed, including the establishment of the ENEN Association in 2003 [5] and enabled for the most part bottom-up activities, including pooling the teachers, infrastructures and students. These initiatives did receive important top-down support. ENEN, for example, has been supported for more than 15 years through projects by the European Commission [6]. Many of the top-down activities suggested in high-level documents [1], [2], [3], [4] were unfortunately never attempted, as noted in [7].

Nearly 20 years after the first signs of dwindling nuclear education, the main concerns persist. It is noted that nuclear energy currently has varying degrees of support in the countries of the European Union but education and training is required across all three phases - construction, operation and decommissioning - of a nuclear plant. It is therefore imperative that education and training programs exist to support the full life cycle of nuclear power plants.

This paper develops some aspects of the EU wide strategic agenda for nuclear education, training and knowledge management [8], which is being developed in part within the ENEN+ project [9] to support and consolidate the efforts of the nuclear stakeholders to attract, develop and retain new talents. The paper outlines and substantiates the current status of the nuclear education, training and knowledge management (ETKM) and most important actions required for the EU to regain its leading role in the nuclear power and non-power disciplines, including reactor engineering and safety, geological disposal, radiation protection and medical applications. The sheer complexity of this challenge calls for high level of support, coordination and partnership between all nuclear stakeholders, especially those involved in the decision-making.

2 CURRENT CHALLENGES OF NUCLEAR ETKM

Since the beginning of the century, the European commission has been strongly supporting the EURATOM Fission Training Schemes (EFTS). EFTS are built on the principles of common qualification criteria, common mutual recognition systems, and the facilitation of teacher, student and professional mobility across the EU and beyond. To date, they have already resulted in a wide range of measures targeting the development of nuclear E&T programs at universities, research institutes and industrial training providers.

One of the main outcomes of the EFTS is European Nuclear Education Network (ENEN – www.enen.eu). More than eighty members of ENEN, supported by the projects cofounded by the European Commission (EC), have been working together to provide sustainability and further development to the initiatives born within the EFTS. Examples of recent initiatives supporting the continuous growth and development of nuclear education and training through cofounding by the European Commission include Horizon 2020 projects ANNETTE [10] and ENEN+ [9].

The main goal of ANNETTE was to enhance nuclear knowledge, skills, competences and thus enhance the nuclear safety culture by:

- connecting E&T groups of existing platforms (SNETP, IGDTP, MELODI, EAN, EURADOS, EUTERP, Alliance, NERIS, EFOMP and others);
- developing an inventory of existing E&T initiatives, mapping how different projects are connected in order to identify overlaps and gaps;
- connecting existing singular databases into one database for E&T initiatives adapted to the needs of every Platform;

- supporting education and training initiatives outside of the European Union, in connection with IAEA and other relevant groups.

ENEN+ acknowledged the remarkable results obtained since the launch of the EFTS initiatives in early 2000s and recognized that the enrolment of students to nuclear disciplines has not yet reached the desired level. A plausible explanation offered was that most efforts of the EFTS have been directed towards creation, improvement and harmonization of E&T programs, establishment of adequate schemes and frameworks for professional development, pooling of resources and means at European level, organizational restructuring and capacity building. These initiatives were indeed greatly needed as a premise to reach expected goals, e.g. for maintaining and transferring the expertise of nuclear professionals to new generations. ENEN+ offered to investigate a different route, including for example direct support to the recruitment. With this, ENEN+ reconsidered at its very roots the pipeline of nuclear workforce, tackling the problems discouraging young students from selecting nuclear subjects as their choice for a future career. One of the main achievements of ENEN+ was to support career enhancement mobility in excess to 45 person-years to more than 500 learners and organize competitions and nuclear summer camps for high school pupils and B.Sc. students.

2.1 Challenges are persisting for decades now

A recent in-depth analysis [11] pointed out that the main challenges in nuclear education and training are persisting after two decades since the first actions to improve the situation were proposed. Some very plausible reasons for the persistence were identified, including:

- Tendency to solve the easy problems first, and
- Tendency to be more concerned with "how" and "what" than "why".

These reasons are consistent with the experience and observations of ENEN, which are briefly outlined below.

2.2 The number of nuclear graduates

In the USA, for example, a national statistic for nuclear engineering graduates [12] has been established in the 1960-ies. The history is depicted in Figure 1, clearly showing the dwindling number of graduates at the end of 1990-ies and the strong growth thereafter, which was to a large extent the result of following the recommendations developed in [1].

Dedicated collection of such data is clearly necessary, as the nuclear engineering graduates clearly fall well below the resolution of the statistical data on tertiary education collected for example by UNESCO[1] or EUROSTAT[2].

The efforts of European Human Resources Observatory-Nuclear (EHRO-N) to collect the numbers of supply and demand of nuclear graduates in EU [13] have resulted in less frequent and possibly also less accurate statistics than in the USA, which may be further refined and improved in the future. The diversity of the education systems being controlled by the EU member states and the proprietary data on the workforce needs by the industry might be among the main reasons for such state of affairs. Nevertheless, the 2833 graduates in nuclear engineering or energy reported in 2010 is much more than the 2167 reported in 2017 [13] and might confirm the existence of persistent challenges causing the dwindling of the EU nuclear education.

[1] http://data.uis.unesco.org/ Natural Sciences, Mathematics, Engineering….

[2] https://ec.europa.eu/eurostat/databrowser/view/sdg_04_20/default/table?lang=en, Science, mathematics and computing, engineering, manufacturing and construction

The distribution of the 2017 EU nuclear engineering and energy graduates by the gender and the level of degree is depicted in Figure 2

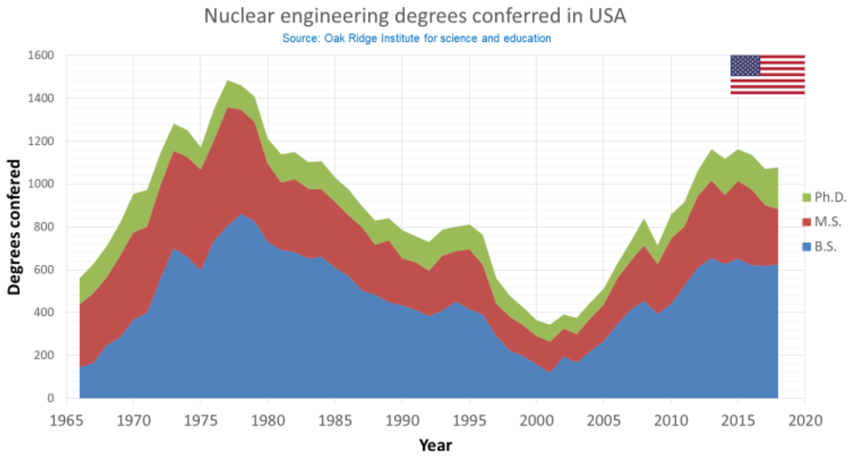

Figure 1: Nuclear engineering degrees conferred in USA (1966-2017) [12]

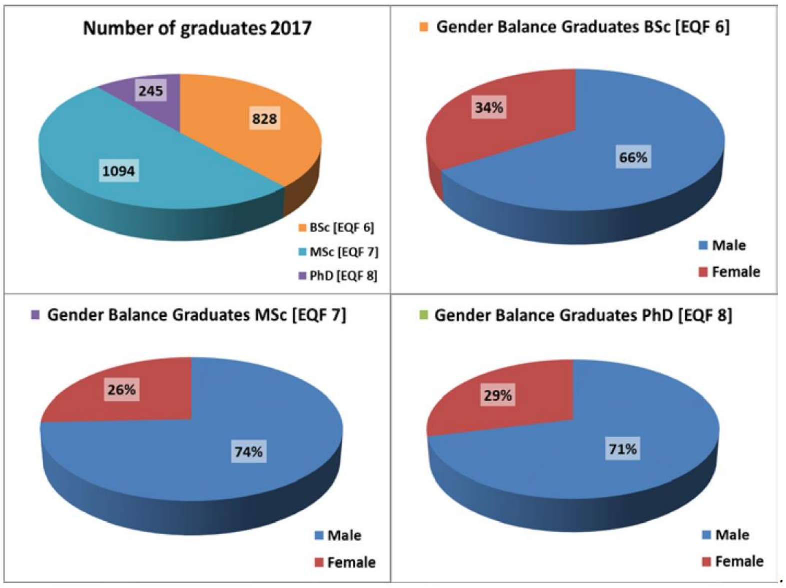

Figure 2: Number of graduates and gender balance between students and education levels in nuclear engineering and nuclear energy studies in 2017 [13]

2.3 “Know-why” vs. “know-how”

High tech industry, including nuclear, depends on people with very diverse degrees and specialties of education and training. The quest for efficiency, stimulated in part by declining nuclear education, the pressures by competition and evolving regulations, to mention a few, might guide the industry towards more internal training, directed naturally much more towards “know-how” than ‘know-why’. Important driver towards such developments may also be the fact that the highly safe industries strongly rely on “know-how” documented in considerable details in operating procedures and regulations. An illustration of main differences between the “know-why” and “know-how” is given in Figure 3.

The dwindling higher nuclear education, aiming at “know-why”, might be therefore compensated, at least for a short while, with more intensive training (e.g., “nuclearization” of non-nuclear graduates) by the industry, aiming at “know-how”. In this way, the main pipeline for attraction and development of the new nuclear talents becomes the “nuclearized” pipeline at the expense of the "nuclear" pipeline (Figure 4). This is another possible perception of the challenges in the nuclear education that persists since the 1990-ies.

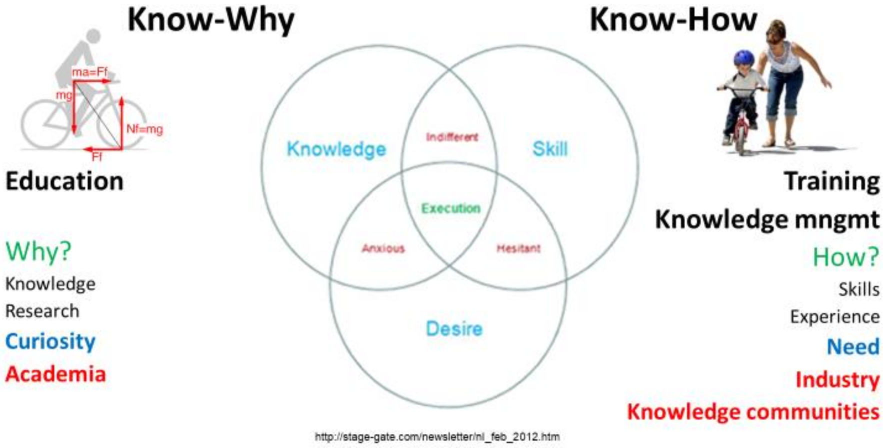

Figure 3: Main features of the "know-why" and "know-how" [14]

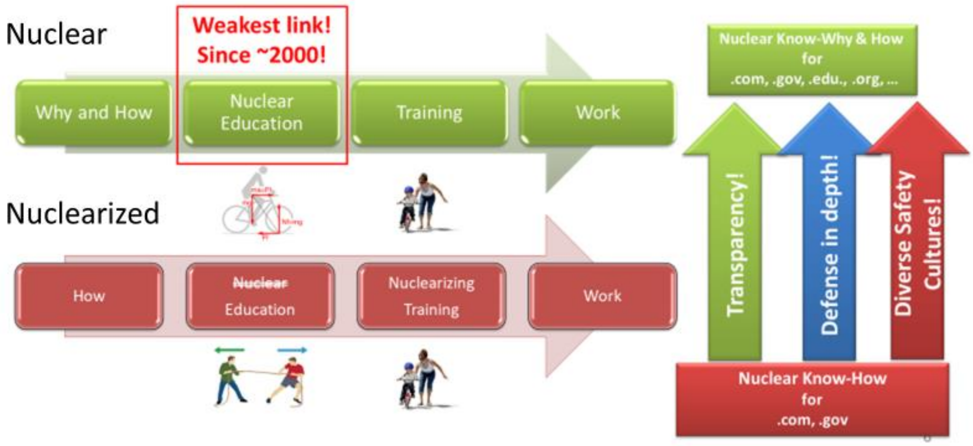

Figure 4: The main nuclear talent attraction and development pipelines

In the short term, the prevalence of the "know-how" or "nuclearization" approach may appear to increase the efficiency and the safety record of the industry. In the medium and longer term, however, the prevalence of the "know-how" acquired in proprietary trainings may contribute to some important risks, which might develop gradually and intensify with time as a surprise to the community. One risk is the reduced potential and need for innovation, usually followed by the loss of competitiveness and the interest of young creative talents. This might offer a possible explanation for the persistent diffusion of nuclear experts from EU based utilities to other service providers in the period 2010-2018 (Figure 5, [13]).

Another major risk might be a perception of poor transparency of industrial expertise towards the public. Preferential internal and proprietary training could namely, as collateral damage, further disable the interest for and performance of the publicly available nuclear higher education. After a decade of two of such developments, one might notice absence of nuclear expertise outside of the industry, which may seriously degrade the public perceptions on the safety, reliability and credibility of all nuclear facilities.

Furthermore, such approach might also be seen as a serious deficiency in the defence in depth: Saito [15] for example claims that one of the causes of the Fukushima Daiichi accident were poor decisions taken by too little nuclear engineers in the utility, which could not be detected efficiently by too little nuclear engineers in the regulatory body. Too little nuclear engineers in the society at large then finally overlooked the poor decisions by utility and regulators, resulting in the failure of the last level of defence in depth of knowledge: society at large.

Sector	2010 [%]	2014 [%]	2018 [%]
Utilities	51	25	7
Vendors & Big suppliers	18	4	4
Research and Design	13	15	13
Design, engineering, manufacturing and maintenance	7	36	36
Waste Management & Decommissioning		14	7
Regulatory authority and TSOs		4	16
Fuel fabrication, enrichment and supply		1	16
Consultancy		1	2
Academic			1
Training provider			0
Others	11		

Figure 5: Distribution of nuclear experts in nuclear sectors in 2010, 2014 and 2018 [13]

2.4 Independent nuclear "knowledge communities"

Many nuclear 'knowledge communities' have developed over the decades of utilization of nuclear power and non-power technologies. These can be seen as a natural consequence of increasing complexities in technologies and regulations and the clear tendency towards the "know-how" and "nuclearization".

Many of the nuclear 'knowledge communities' have already approached ENEN for cooperation and coordination. These include nuclear engineering, radiation protection, management of radioactive waste, fusion engineering, medical applications, nuclear security, nuclear safeguards, nuclear materials, nuclear safety assessment, nuclear culture for safety, radio chemistry and decommissioning of nuclear installations. There are some nuclear 'knowledge communities' that have not yet sought cooperation or coordination. The most important among those might be the nuclear regulatory community.

The possibly unwanted or unexpected consequence of the strong and increasingly independent nuclear "knowledge communities" is competition for talents between nuclear communities rather than cooperation of nuclear communities in competition for talents with other complex or high technologies.

Another unwanted consequence might be a perception developing among the prospective students of increased complexity - and therefore reduced attractivity – of nuclear education and training.

2.5 Steady Supply or Highly Cyclic Demand

Experience shows that construction of nuclear power plants comes in waves (e.g. in Europe the vast majority of the facilities were built in the 1970s and 1980s). Consequently, the recruiting and development of personnel for operation and other stakeholders has also been done in waves (e.g. 1970 and 1980s for the first wave, 2010-2020s for the replacement of the first generation). This will be, assuming that every nuclear power plant is with us for a century or more, repeated also in the future. Between those waves, the demand for the new personnel is generally very limited.

In general, the (high) educational systems need sustainable and stable conditions and might need very specific support for the times with low demand to avoid university departments being shut down on the grounds of too low demand when professors retire. Such support may be necessary, among others, because of rather long times involved in the development of new faculty (e.g. up to 20 years).

3 DISCUSSION

A common trait of the current challenges mentioned above appear to be absence of strong strategic guidance or, in other words, too strong reliance on the bottom-up approach practiced independently by each of the nuclear stakeholders involved. One might say that the bottom-up approaches to revive the nuclear education and training practiced during the last two decades were, on the whole, satisfactory to maintain the education systems and generate warnings to the decision makers. They were unfortunately not satisfactory to attract many new talents and did not lead to substantial innovations to nuclear (power) technologies.

The proclaimed closures of operating plants in many countries may have contributed in part to further dwindling of nuclear education. On the other hand, it appears that the countries that decided to cease operation of nuclear power plants also felt a much stronger need to give power to the top-down approaches to the nuclear education and training: it appears that Germany is the only member state in the EU with a dedicated nuclear education strategy published in 2020 [17].

A number of countries in EU and beyond did publish strategic documents supporting the research, innovation and operation of nuclear facilities. A common trait is that they rely on the nuclear research as the main driver for the workforce development (see [8] for summary and citations). One may therefore conclude that there is large degree of agreement at the strategic level that "know-why" and nuclear education should have a preference over the "know-how" and nuclearization.

An interesting observation is that nuclear education in China, with more than 3000 nuclear students enrolling annually in more than 70 universities, is discussed in the section on nuclear safety [18], suggesting that the responsibility is with the nuclear regulator.

4 STRATEGIC VISION AND GOALS

More of the top-down (strategic) approaches, together with the strengthening of successful bottom-up approaches, appear to be needed to maintain and further develop the nuclear education and training. This includes for example the policy studies to review current and planned future activities and development and implementation of nuclear education, training and knowledge management strategies consistent with the long-term visions/plans for development and implementation of nuclear technologies.

In the future, we need to overcome the tendency to solve the easy problems first. The more difficult approach will have to fit not only the boundary conditions dictated by the markets, but will also require long-term strategic planning, communication, cooperation, long term investment, etc., of all nuclear stakeholders. A nuclear power plant is namely with us for a century or more, and changes in the society and technology within a century are enormous. The nuclear stakeholders should not only follow such changes, but should also strive to co-create these changes through much more intensive involvement in the research.

ENEN is, as a part of the ENEN+ project, contributing to this with a proposal of the European strategic agenda for nuclear education, training and knowledge management [8]. This document will be offered as the basis for discussion to all nuclear stakeholders and will hopefully serve as the basis for a joint action of all nuclear stakeholders. The most important strategic goals developed in [8] include:

- Attract new talents
  - Visible job opportunities
  - Pro-active role of future employers including directions to nuclear universities

  - Appealing activities for high school pupils and teachers
  - Appealing activities for B Sc students
  - Strategic approach with estimated future needs (specializations, degrees and numbers)
- Develop new talents
  - Excellent higher education including ample and interesting research opportunities
  - Extracurricular activities for students, e.g. internships in industry and regulatory bodies (mixing cultures, developing social & communication skills), access to research infrastructure, mobility support and career guidance (mentorship from academia and industry, coaching by older students, alumni, etc)
  - Professional training (proprietary and open for students)
  - Strategic approach with estimated future needs (specializations, degrees and numbers)
- Retain attracted and developed talents
  - For existing staff, intensity lifelong learning and support for career development, provide creative and interesting working environment
  - Better prepare for the needs and perceptions of the new generations (e.g., X, Y, Z and Millennials).

Further integration of strategic agendas of different nuclear communities, as for example the Sustainable Nuclear Energy Technology Platform [16], is also recommended in the future.

5 CONCLUSIONS

Nuclear knowledge has been one of the major achievements of mankind. It has made many significant contributions to science and technologies beyond nuclear power. Examples include diagnostics through imaging and a variety of therapies in medicine, sterilization in food processing, and diagnostics in industry, forensics, archaeology and geology, among others. We believe that the time has come for all nuclear stakeholders to establish and follow a common strategic goal: preserve, maintain and further develop this valuable knowledge for present and future generations.

The sheer complexity of this challenge calls for high level of support, coordination and partnership between all nuclear stakeholders, especially those involved in all levels of decision-making.

ENEN is, as a part of the ENEN+ project, contributing to this with a proposal of the European strategic agenda for nuclear education, training and knowledge management [8]. This document will be offered as the basis for discussion to all nuclear stakeholders and will hopefully serve as the basis for a joint action of all nuclear stakeholders.

ACKNOWLEDGMENTS

This work has been co-founded by the HORIZON 2020 ENEN+ project grant 755576 NFR-2016-2017.

REFERENCES

[1] M.L. Corradini, M.L. Adams, D.E. Dei, T. Isaacs, G. Knoll, W.F. Miller, K.C. Rogers, The future of university nuclear engineering programs and university research and training reactors, U.S. DOE NERAC Committee Report, 2000.

[2] OECD/NEA, Nuclear education and training: cause for concern? ISBN 92-64-18260-8, 2000. URL: https://www.oecd-nea.org/jcms/pl_13372/nuclear-education-and-training-cause-for-concern?

[3] CCE Fission, How to maintain nuclear competence in Europe: A reflection paper prepared by the CCE-Fission working group on nuclear education, training and competence, European Commission, EUR 19787 2001, https://inis.iaea.org/search/search.aspx?orig_q=RN:34021824.

[4] International Nuclear Safety Advisory Group (INSAG), Maintaining knowledge, training and infrastructure for research and development in nuclear safety, ISAG note, IAEA, 2001.

[5] F. Moons, J. Safieh, M. Giot, B. Mavko, B.R. Sehgal, A. Schäfer, G.V. Goethem, W. D'haeseleer, European Master of Science in Nuclear Engineering, Nucl Eng Des 235(2) (2005) 165-172.

[6] L. Cizelj, J. Starflinger, V. Decobert, B. Bazargan-Sabet, F. Tuomisto, M. Coeck, P. Anzieu, J. Roberts, T. Kokalova Wheldon, P. Dieguez Porras, 15 Years of the European Nuclear Education Network (ENEN Association), Proceedings of the 26th International Conference on Nuclear Engineering, 2018, Vol 8, 2018, p. V008T12A007.

[7] OECD/NEA, Nuclear Education and Training: From Concern to Capability, Nuclear Development, Nuclear Energy Agency, Organisation for the Economic Co-operation and Development, Paris, France, 2012.

[8] Proposal of the EU wide ETKM strategy, Deliverable 6.2, ENEN+ project, 2021.

[9] ENEN+, Attract, Retain and Develop New Nuclear Talents Beyond Academic Curricula, H2020 project grant 755576 (http://plus.enen.eu).

[10] ANNETTE, Advanced Networking for Nuclear Education and Training and Transfer of Expertise, H2020 project grant 661910 (www.annette.eu).

[11] B.-J. Chung, Attracting a High Quality Nuclear Workforce Attracting a High Quality Nuclear Workforce Attracting a High Quality Nuclear Workforce -Recollection of the NKM, IAEA 3 Int'l Conf. on Human Resource Development for Nuclear Power Programme, IAEA, Gyeongju, Korea, 2018.

[12] Oak Ridge Institute for Science and Education, Nuclear Engineering Enrolments & Degrees Survey Data: 50-Year Trend Assessment, 1966-2015, 2017. https://orise.orau.gov/stem/reports/ne-assessment-2017.pdf.

[13] B. Eriksen, B. Christiansen, R.C. Ramos A.V. Kalleveen, B. Hirte, Results of surveys of the Supply of and Demand for Nuclear Experts within the EU-28 Civil Nuclear Energy Sector, 2019.

[14] L. Cizelj, The role of nuclear higher education in the future of nuclear power, Invited plenary lecture at International Conference on Nuclear Engineering ICONE-19, Tsukuba, Japan, May 19-24, 2019.

[15] H. Saito, Education as the Weakest Institutional Link in Japan's Nuclear Regulation, The Journal of Social Studies Education 5 (2016) 33-55.

[16] F. Roelofs (ed.), SNETP Strategic research and Innovation Agenda, Sustainable Nuclear Energy Technology Platform SNETP, Brussels, 2011 (https://snetp.eu/wp-content/uploads/2021/09/SRIA-SNETP-1.pdf).

[17] Federal Ministry for Economic Affairs and Energy (Germany), Strategy for Competence Building and the Development of Future Talent for Nuclear Safety, 2020 (https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/strategy-for-competence-building-and-the-development-of-future-talent-for-nuclear-safety.pdf?__blob=publicationFile&v=2).

[18] Nuclear Safety in China, The State Council Information Office of the PRepublic of China, 2019 (http://english.www.gov.cn/atts/stream/files/5d6ddd5dc6d0cc300eea7734).