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# “Give Energy to Your Study”: Students Worldwide Gather in Europe To Design Future Materials for Energy Storage and Conversion

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**ABSTRACT:** Global warming, finite fossil-fuel supplies, and urban pollution rapidly change the landscape of energy research worldwide and our training and education programs must change accordingly. Because of the natural intermittency of many renewable energy sources, there will be a far greater need for advanced electrical energy storage technology. Establishing highly diversified education programs that embrace worldwide scientists in this strategic area of science is of primary importance for bringing newly emerging concepts to fruition and securing our future. Five European universities pooled their efforts to create a specific, integrated, European Master’s-level degree program, Materials for Energy Storage and Conversion, which offers high-level education while providing high mobility to students, as well as beneficial knowledge and exposure to relevant industrial settings.

**KEYWORDS:** Continuing Education, General Public, Graduate Education/Research, Upper-Division Undergraduate, Electrochemistry, Nanotechnology, Solid State Chemistry, X-ray Crystallography



## ■ INTRODUCTION

Global warming, finite fossil-fuel supplies, urban pollution, and CO<sub>2</sub> emissions (with transportation accounting for 30% of total CO<sub>2</sub> emissions) together with the foreseeable world population growth (estimated to reach 10 billion people by the year 2050) are conspiring to make the development of advanced renewable energy technologies a worldwide imperative. A future “clean energy” economy must mitigate CO<sub>2</sub> release through chemical, physical, or biological CO<sub>2</sub> sequestration. H<sub>2</sub> is a potential alternative fuel for hybrid electric vehicles (HEVs), and humans must increase their use of renewable energy sources such as wind, solar, biomass, wave, and geothermal.<sup>1–3</sup> Because renewable energy sources are intermittent (e.g., the wind does not blow on demand), there is a pressing need for advanced technologies of electrical energy storage. Turning to transportation, it is apparent that in the coming years we will at least partly shift from internal combustion engines to electrical vehicles. High-performing energy storage devices are desperately needed if humans are to swiftly and successfully transition from a society based on burning fossil fuels to one powered by renewable and carbon-neutral energy resources.<sup>4</sup>

Electrochemical, thermal, mechanical, and magnetic devices are among the possible candidates for the next generation of energy storage technologies. Developing such technologies is a

complex task, so interdisciplinary collaboration is needed among the fields of materials science, chemistry, electrochemistry, engineering, and physics. The landscape of energy research is rapidly changing worldwide, so academic and education programs must change accordingly. Establishing highly diversified, interdisciplinary education programs and attracting scientists from around the world is crucial for bringing new concepts to fruition in this strategic area of science and securing our collective future.<sup>6,5</sup> Mindful of these needs, in 2004, several European universities pooled their efforts to create an integrated European Master’s-level degree program. This program, Materials for Energy Storage and Conversion (MESC), provides students with a high-level education, supports a mobile student population, and offers students considerable knowledge of the industrial world.

At roughly the same time that MESC was founded, the European Community launched an education program called Erasmus Mundus Master Courses. This program enhances the visibility and attractiveness of European higher education to students from non-European countries.<sup>7</sup> The Erasmus Mundus program also offers new perspectives for higher education in

Europe by implementing fully integrated curricula at the Master's level. The program involves several European partner universities and offers a specific student mobility scheme within the MESC Master Consortium. Erasmus Mundus grants of up to 20,000 Euros per year are provided to typically 20 selected non-European students from around the world to cover their travel, living, and accommodation costs. In 2009, the scholarship program Erasmus Mundus II was extended to European students, to "non-European institutions", and to the doctorate level.<sup>7</sup> Extensive mixing of different cultures to create a cultural melting pot is a strength of this education program: top-level students learn by sharing their views with others, providing them with an opportunity to open their minds to new concepts.

In 2006, the MESC received the "Erasmus Mundus" label in recognition of its mobility and high-level lectures by key players from universities and industries in the field of materials for energy storage and conversion. Five European universities joined forces to create an integrated teaching program that couples regular quality surveys with strong involvement in each partner university to promote smooth mobility and assistance to students. In accordance with the spirit of the Erasmus Mundus concept, partner universities have developed common policies for: selecting talented students; defining tuition fees (2000 Euros/semester); creating an integrated teaching program; setting competitive quality-assessment and ranking rules; and providing a diploma jointly awarded by three universities in France (Amiens, Marseille, and Toulouse), one in Spain (Cordoba), and one in Poland (Warsaw).<sup>8</sup> In 2010, the MESC Consortium successfully applied to the Erasmus Mundus II program and got the Erasmus Mundus label for 5 extra years, starting in September 2011. For that purpose, the master Consortium was enlarged to include two new members from outside Europe: Drexel University (Philadelphia, PA, coordinator Prof. Y. Gogotsi) and Xiamen University (Xiamen, P.R. China, coordinator Prof. Y. Yang). Drexel and Xiamen will be involved in the last semester of the training program (Master Thesis, see below)."

## ■ CURRICULUM AND MOBILITY SCHEMES

MESC is unique because it brings together scientists from different European universities who are working on energy storage and conversion devices. No single university in the MESC program could have assembled so many experts on its own. The success and strength of MESC's curriculum relies on the complementary expertise of these teachers. Thanks to this cross-university asset, MESC attracts students from around the world and is recognized by research centers everywhere.

MESC's curriculum combines the fundamental topics of materials science (i.e., solid-state chemistry, materials and nanomaterials synthesis, electrochemistry, characterizations, and analysis techniques) and focuses on energy storage and conversion applications for photovoltaics, fuel cells, rechargeable batteries, and supercapacitors. The two-year Master's program consists of three semesters ( $S_{1,2,3}$ ) of academic lectures, tutoring, and labwork and one semester of scientific training ( $S_4$ ) in an academic laboratory or a company to complete a "Master's thesis".<sup>8</sup> One highlight of the MESC master course is the mobility scheme proposed to the students (24–30 students per class) who are equally split in two universities for  $S_1$ , reunited to attend classes in Warsaw for  $S_2$ , and split again in two universities for  $S_3$ . This arrangement allows MESC students to benefit from the expertise of each partner institution in specific areas of energy-related materials.<sup>9–20</sup> This

arrangement also fosters mixing of people from different cultures and promotes a high level of interaction within the class. The program structure also provides a unique opportunity for students to learn about various European academic traditions.

Another attractive aspect of MESC is that it offers more to students than just instruction and research in the core scientific disciplines. The MESC program offers students short courses and meetings related to many aspects of social life. For instance, to raise student awareness about gender issues, which is a fundamental concern for the future of science and technology,<sup>21,22</sup> MESC organized an international seminar called Women in Science that was held in Warsaw in March 2008.

## ■ PARTNERSHIP WITH THE ALISTORE EUROPEAN RESEARCH INSTITUTE

Although offering a Master's program to train the future generation of talented scientists to address the energy storage and conversion concern is important, this educational program must be strongly linked with the research and industry communities that will offer most of the job opportunities. In 2003, 16 European research laboratories, aware of the limitations of lithium-ion technology and excited by the possibilities of nanomaterial electrodes compared with their bulk-material counterparts, decided to pool their efforts by creating the ALISTORE Research Network of Excellence.<sup>22</sup> The European Commission sponsored this network from December 2003 to December 2008 with 5 million Euros. It has evolved into the ALISTORE European Research Institute (ALISTORE-ERI) and is currently funded by a consortium of companies.<sup>22</sup>

In addition to establishing a new school of thought regarding development of the next generation of advanced Li rechargeable batteries, one of ALISTORE's main objectives was the creation of MESC. Hence, the fruitful relationship between MESC and ALISTORE-ERI, is a collaborative network that currently unites 23 European universities and industrial research laboratories within Europe in the "Nanomaterials for Energy Storage" research area. ALISTORE-ERI is additionally sponsored by a European Industrial Club (EIC), which consists of 17 European industrial partners, including automotive, materials, and battery manufacturers. This collaboration between MESC, ALISTORE-ERI, and EIC structures produces a unique and unprecedented European platform for providing high-level training from which all participants benefit. The MESC Master's program helps to disseminate internationally the new ideas emerging from ALISTORE-ERI on the outstanding properties of nanomaterials with respect to energy storage and conversion.<sup>9–20</sup> Furthermore, EIC members contribute to MESC by offering key seminars and training periods to the students. This contribution keeps students current on recent technological advances and breakthroughs in the world of industry.

Yet another of MESC's positive attributes is the six-month training that students must do at either a university or an industrial laboratory to produce a mini-thesis. More than just an opportunity to improve their knowledge, this training period is also a chance for students to interact directly with the research world in both the laboratory (including Drexel and Xiamen Universities) and throughout all of ALISTORE-ERI. This experience helps students generate their own networks for future applications to Ph.D. programs or research engineer positions. And, because MESC students originate from many different countries (an average of 15 countries are represented in each

class), a worldwide network of specialists is created who (we hope) will become ambassadors for clean energy storage and conversion technologies. High mobility is encouraged even further at the Ph.D. level by exchange of shared Ph.D. students between institutions of the network.

## ■ MASTER QUALITY ASSESSMENT

Assessing and maintaining quality is indispensable to MESC's success, a practice that starts with a highly selective enrollment procedure (Figure 1). Each application is independently evaluated by at least two members of the MESC pedagogic committee. Well-established grading coefficients are used, including academic excellence, letters of reference, an essay on energy-related issues, and coherence of academic background relative to the Master's main topics. This assessment system improves MESC's quality and facilitates tracking the future of students after they complete the degree. Quality assessment is performed by collecting survey forms twice every semester, once upon the students' arrival and again before they leave. Students are asked to evaluate the quality of the universities' academic curricula and facilities. These quality-assessment processes are

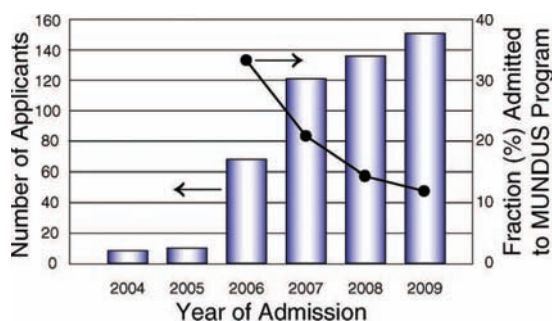


Figure 1. MESC selection process: total number of applicants (left) and percentage of selected applicants in the MESC Mundus Program.

intended to guarantee high-quality education. The full process is iterative.

MESC's quality-assessment process is as follows. First, a quantitative strategy was developed to better understand each student and his or her academic perceptions of the MESC program. The research strategy was based on a careful selection of identifiable and quantifiable components of the teaching-learning activities, which took into account the previous experiences of the participating universities. The different components are collected in the form of a questionnaire oriented at four levels: student, professor, supervisor, and coordinator or manager. Survey forms are prepared by the quality management group, which is composed of administrative staff from the international offices of the five university partners and outside experts, particularly experts from industrial partners.

The student survey on teaching units contains questions on consistency with the European credit transfer system (ECTS), and the planning and development of teaching activities. This survey also has questions on the topics, planning, and duration of the activities; the activity of the supervisor; and the impact of the work at scientific and personal levels. Finally, the student survey on management and coordination has questions on the information and assistance students receive, the development of learning activities, and students' overall impression. Analysis of the surveys is carried out with strict independence from professors and students by using all the necessary statistical and data-analysis tools provided by a central university service.

In general, analyses of the surveys show that the students strongly appreciate MESC's teaching methods, the mobility it provides, and the mixing of cultures and sensibilities regarding future energy-management issues (Figure 2). At the end of the course, graduate students are tracked by several European laboratories for Ph.D.s as well as companies for research and development engineer positions. Currently, all MESC graduates are employed: 85% are working on a Ph.D., and 15% work in companies.

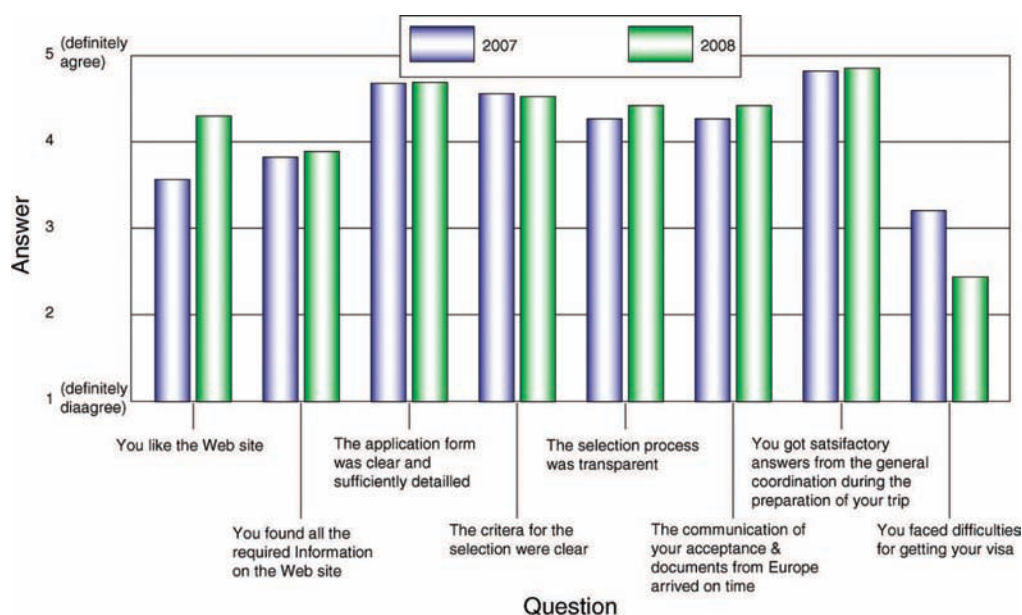


Figure 2. Comparison of student responses to MESC survey questions on quality assessment.

MESC was also the driving force for the creation of a novel national teaching program in the field of sustainable energy at the Warsaw University of Technology by the faculties of electrical engineering; physics; and the School of Advanced Materials and Chemistry Technology. In fall 2009, this program enrolled 60 undergraduate students from Poland and other eastern European countries. The hope is that the Warsaw program will increase the number of MESC candidates from former Soviet Union countries, as that number is currently below the program's expectations.

## ■ CONCLUSION

MESC, which since 2011 includes Drexel University and Xiamen University, provides novel teaching programs to prepare a pool of highly competent scientists who are well trained on energy storage matters. MESC's strength stems from its full integration with ALISTORE-ERI and EIC to create a unique structure that unites and supports education, research, and technology transfer to help produce a bright future for the European energy storage and conversion industry for years to come. Through this education process, industries will have access (in the short term) to a pool of Erasmus Mundus students for Master's level and Ph.D. work, and (in the long term) to the next generation of scientists required for the growth of their businesses. These efforts will also benefit European research labs, which are short of well-trained researchers who can address energy-related problems. So long as MESC continues to strive for excellence, recruit the best students from around the world, and deliver a diversified and challenging educational program, it will benefit students, research laboratories, and not just Europe, but also the rest of the world.

## ■ AUTHOR INFORMATION

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