

# Education for Resource Efficiency in Manufacturing Industries EREMI

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The EREMI project is a 2-year project funded under the ERASMUS+ framework programme and its team has developed and will validate an advanced higher education program, including life-long learning, on the interdisciplinary topic of resource efficiency in manufacturing industries and the overall system optimization of low or not digitized physical infrastructure. All of these will be achieved by applying IoT technologies towards efficient industrial systems, and by utilizing a high-level educated human capital on these economically, politically, and technically crucial and highly relevant topics for the rapidly developing industries and economies of intensively economically and industrially transforming countries – Bulgaria, North Macedonia, and Romania. Efficiency will be attained by utilizing the experience and expertise of the involved German partner organisation.

*Keywords* – manufacturing, resource efficiency, higher education.

## I. INTRODUCTION

The project EREMI (2020-1-BG01-KA203-079076) has started in 2020 and its team has elaborated a curriculum for all modes of higher education in the field of resource efficiency in the manufacturing industries.

The contents of the EREMI education program will underlay the open-source rules and be publicly accessible online for all relevant European stakeholders and citizens through the EREMI website. The final product of the project will be a free of charge online-based interactive teaching/learning platform, built-in Moodle, targeting university students and postgraduate professionals, and serving relevant universities, pupils, and companies for the fast and efficient professional education on

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this crucial topic for EU-wide industries, and especially to the industry in transformation, as in the region of Plovdiv (Bulgaria) due to the rapid industrialization trends and the lack of adequately educated engineers in this strategic industrial engineering and operations area. This product is being created, refined and validated during the entire project runtime.

## II. CONTEXT

### A. A brief state of the art

Due to the global acknowledge of the importance of resource efficacy and proficiency, during the last decade many groups of researchers tried to develop effective and innovative techniques *aware* of the importance of resource efficiency for different type of industries. In [1] the authors discussed several mechanisms that enable high education institutions to contribute to knowledge application related to green technology. In [2] the authors present the conclusions drawn based on the results obtained by the Eu project "European Network of Innovative Learning" (NIL), while in [3] are presented the conclusions drawn after implementing 'Innovative Project in Learning and Teaching' grant in Built Environment at Heriot-Watt University. Both studies conclude that finding attractive topics, giving real life examples *and* offering hands-on applications were the key to develop an efficient training. Recently, after the Covid Pandemic, intensive research has been develop towards developing on-line remote access classes for resource efficient engineering. In [4] the authors presented an optimization method that models the process or resource efficient management for high education level based on a multi-stage technique that distributes the information based on the directions and specialties of each group of students, the regional needs and the educational resources available. In [5] the authors make a comprehensive state of the art regarding Industry 4.0, describing the skills that are supporting it, from independent robots to cloud and fog data centres, augmented reality and security issues and the needs that will emerge with respect to student courses content and aptitude wants. The authors of [6] make an analysis of the effects of I4.0 on the education sector too, emphasizing also that the students from different regions are not well prepared to acknowledge the technological skills necessary to implement the new technologies, and thus the educators have to find means and methods to present these technological findings in an affordable way. In [7] the authors studied the impact of Covid pandemic in different industrial sectors, like automotive, energy systems, tourism and agriculture and the challenges imposed to the educational system.

## *B. EREMI in a nutshell*

The EREMI team, consisting of UFT (University of Food Technologies; Plovdiv, Bulgaria as project leader), HSO (Hochschule Offenburg, Offenburg, Germany), UKLO (University St. Kliment Ohridski Bitola, Republic of North Macedonia), BEIA Consult, Bucharest – Romania, UPB (University "Politehnica", Bucharest, – Romania), has developed and validated together an advanced higher education program for Life Long Learning, on the interdisciplinary topic of resource efficiency in manufacturing industries, as well as the overall system optimization of physical infrastructure by applying IoT technologies, towards sufficiently educated professionals.

Currently Bulgaria, Romania and North Macedonia are facing a serious challenge in the higher and adult education and requalification levels, crucial for the success in the current (re) industrialization situations there.

Bulgaria and in particular the geographical and economic region of Plovdiv are facing highly intensively this challenge and therefore are willing, by getting a qualified support by a relevant and experienced partner from Germany to develop a higher education program addressing the improvement of resource and in particular energy efficiency in industrial infrastructures by using Big Data and Artificial Intelligence as a tool for the virtualization of physical production facilities. This issue has a high environmental and energy transition relevance as well. Quite similar is the situation in Romania.

North Macedonia has experienced in the recent years an intensive wave of establishment of production facilities of many internationally active companies and has the chance, in the sense of this trend and before becoming an EU member state, to prepare well its education system for the challenges of the intensive re-industrialization.

In all three previously mentioned countries, the resource and in particular energy consumption dedicated to industrial manufacturing is keeping the highest rate compared to all other economy sectors. In order to address and reverse this trend by adequately educated professionals on the field, developing and implementing innovative higher education and technological trends, and being supported by an experienced partner from Germany, a country already experienced this step of its industrial development in its younger past, the EREMI team is developing higher education content and particular B.Sc., M.Sc. and doctoral curricula on the field, and verifying it at and/or supported by all five participating project partners.

## *C. Challenges faced by EREMI*

The EREMI project addresses the obvious and intensive need of adequately interdisciplinary educated engineering professionals on the field of resource efficient production systems in

Bulgaria (UFT), Romania (UPB, BEIA), North Macedonia (UKLO) and Germany (HSO). The project team performs this action by dealing with the resource efficient manufacturing as with a system of systems, including its subsystems as energy efficiency in pneumatic and hydraulic systems, digitalization of existing physical systems, IoT, Big Data analysis, predictive

maintenance, entrepreneurship etc. By creating a highly innovative crosscutting educational and respectively learning content, and based on this establishing new subjects, courses and programs for the engineering higher education in these countries and in Germany, at the partner entities, the EREMI team intends to support first of all the higher education organizations, but also the industries and respectively regional economies in facing the challenges of the constantly advancing technologies and the rising need of interdisciplinary knowledge of the engineering professionals engaged in their realization.

Globally, approximately one-third of the electricity end-use originates from the industrial sector. In Bulgaria, industrial electricity use is for about 43% of the country's total electricity use (National statistical institute, BG -Overall energy balance sheet, 2016). Industrial electricity use in Bulgaria is mainly dominated by a few high energy-intensive sectors mainly from the primary industrial sector.

However, at some industries as Glass Production and production facilities with high level of automation this percentage goes up to 45-50%, UFT has already performed a study based on direct measurement in 8 production facilities operating in Bulgaria from different industries and results confirm the global trends: while there are no other verified data for Bulgaria, an average of roughly 15% is assumed as realistic.

Another challenge promises to have a high improvement potential: the predictive maintenance, enabled by IoT and virtualization of physical systems - a field on which HSO is a leading research and education partner in the EU, which in this project is being supported by UFT, UPB and UKLO towards the integration of this topic in teaching.

The EREMI consortium, led by UFT, is developing an innovative interdisciplinary strongly online based content for subjects, courses and programs mainly for Master, but also for Bachelor students, able to be taught in any situation online, and will prepare it for the establishment of an international Joint Degree Program between them, which should be approached and accredited after the project runtime, due to the specific time frames for this, which are not always perfectly predictable. The resource efficiency in manufacturing is being covered mainly by UFT and UKLO, supported by UPB, BEIA and HSO.

## *D. The EREMI project consortium and the tasks distribution*

EREMI is being performed and conducted as a living lab activity. It aims the co-development of an innovative higher education learning content and digital platform, which require the active involvement of several stakeholder groups - students, teachers, industrial partners, policy makers etc.

The partners involvement and responsibilities, as well as the participants involvement will look as follows:

UFT is coordinating the project. On the content side it is actively developing and implementing the EREMI learning content on the following educational and practical fields: ■machine engineering; ■electrical engineering; ■system engineering; ■pneumatics; ■energy efficiency; ■industrial economics.

The choice of participating students is being done by their professors, who will perform a pre-selection of the most motivated and best performing students. In the second phase,

the students will select at which thematic fields they are able and prefer to participate as test students.

HSO is in charge of the ITP general setting and launch, as well as of the content development on the educational areas of: ■Sensing systems; ■ Edge computing; ■Communication systems. HSO is having the chance to involve participants at its running adult education programs, aiming to test the EREMI contents along their education, at its Adult Education Center.

UPB is in charge of the content development of the EREMI learning content package on the area of Big Data analytics. It will be able, together with the local support of BEIA, to perform a test implementation row and period of the ITP, and both will involve

BEIA is in charge of test implementation of professional courses on Physical Systems Digitalization and, as mentioned above, will be testing the ITP together with UPB, mainly during adult education workshops at BEIA, mainly for IT professionals.

UKLO is in charge of the EREMI content development on the field of Resource efficiency in production systems and facilities. It will also implement the EREMI content as modules of a Life Long Learning program for adults and seniors, which will be also partially developed during the project runtime.

#### *E. project results: The EREMI learning contents package incl. validation*

UFT is developing and providing a highly Innovative Teaching Program ITP, addressing the resource efficiency in production systems skills for university students and postgraduate professionals (strongly for example in the machine engineering, electrical engineering, pneumatics etc.), which is identified currently as a serious gap by the industries in the entire EU, and especially in Bulgaria - they miss adequately educated engineers. This increase in efficiency will be supported and monitored by Internet of Things (IoT) based technologies, which is another relevant technology direction to make components, machines, systems, and factories future-proof. Apart from the general learning objectives around the Internet of Things and Big Data Analytics, the special topic of energy savings in high-dynamic pneumatics shall serve as a use-case to be explored in-depth. Also, the predictive maintenance is a subject of the EREMI program, as a cross topic area, leading also to high resource savings.

UPB and BEIA are co-developing the ITP, by utilizing their expertise on the field of software, processing and communication for Big Data utilization and integration for energy efficiency in production facilities and buildings, on the side of Education, R&D and practice. They work together on industrial and scientific projects for a long time, and have established their expertise and experience.

HSO is supporting the development of the virtual learning platform (ILT) in a leading role and afterwards embodying the ITP into an Interactive Learning Toolkit ILT and upgrade/adapt the teaching contents. Also, HSO is involving its expertise in the field of retrofit IoT-based devices for status and energy monitoring in production facilities.

UKLO is co-developing the EREMI contents, taking into account its expertise in the area of industrial resource efficiency

and, as only partner of the consortium, and creating a unique Life Long Learning module. It will enable the adult education and professional reorientation of useful labor in North Macedonia which will be strongly needed in the upcoming years due to an even more intensive industrialization development in the country.

UKLO, UPB and BEIA will perform an implementation as a demonstrator case for the new platform, among UFT and the education unit of the industrial zone in and around Plovdiv TEZ. Based on the lessons learnt from the test implementation phase, the ITP and the virtual toolkit will be improved.

The final product of the project will be an interactive teaching/learning platform, targeting university students and postgraduate professional, and serving relevant universities, pupils and companies for the fast and efficient professional education on this crucial topic for EU-wide industries, and especially to the industry in transformation, as in the region of Plovdiv (Bulgaria) due to the rapid industrialization trends and the lack of adequately educated engineers in this strategic industrial engineering and operations area.

The ITP will later on serve as a basis for an International Joint Degree Program on the EREMI topic, which will be carried out by the participating higher education partner organizations, which will be accredited after the finish of the EREMI project runtime, due to the various country specific accreditation criteria and time frame.

The ITP and ILT will serve as a basis for establishing an EU university student network and mobility program, in the framework of a follow-up ERASMUS Mundus project.

A novel format enabling the more efficient knowledge transfer is being developed and introduced by HSO within the project. It is based on augmented reality and offers pre-recorded lectures in relevant industrial environments, combined with static lecture material, which provide a solid knowledge elaboration basis to the students.

#### *F. The EREMI impact*

All five partner organizations - UFT, HSO, UKLO, UPB and BEIA are engaged in the recent years first of all in trying to offer an adequate education content and framework for a decentralized sustainable economic development in the regional and national context, by capacity building on a local level on the field of production engineering and planning.

Therefore, they are uniting efforts and expertise at EREMI towards making a significant step in this direction, by developing and implementing both an Innovative Teaching Platform and an open access Interactive Learning Toolkit, aiming to enable a well-structured, higher professional education based jump of the local, regional and national economies, focused on the manufacturing industries and strengthening A. its role for the sustainable development of the industrial landscape of Europe and B. for making the European Economy, respectively Industries, competitive on the World market in the long term perspective.

UFT traditionally generates and provides in the local and regional context of Plovdiv, the newly industrial capital region of Bulgaria, high qualified professionals on the field of Food Production, Processing, Manufacturing Industries and

Marketing. Building up on this, by involving the EREMI learning contents, UFT aims to make the regional industries, by innovating the education for engineering professionals involved in its planning and operation, more competitive and sustainable on international level. The Region of Plovdiv is attracting constantly a large amount of new manufacturers from the EU and the entire World, and by developing and implementing EREMI, UFT will do a significant contribution for bringing the regional and national manufacturing industries on a new level - Industry 4.0, enabled by the professionals, educated in the EREMI context.

HSO has generated highly innovatively and agile thinking and working engineering professionals on the field of production, production processes and infrastructure digitalization, as well as automation, on regional level and by this strengthened the sustainable industrial and economic development of the region of Germany - Baden-Württemberg - with the highest rate of innovative SMEs in the context of Germany. It will do it in an even more efficient and innovative way by offering and implementing the EREMI education contents into its existing courses and programs, mainly in the Master degree programs, but also in its Adult Education Program Set.

UKLO has traditionally provided well educated machine and industrial engineering professionals to the local and regional highly dynamically developing industries in the recent decades. It plans to address a crucial and highly innovative part of the education - Life Long Learning - in the thematic context of EREMI, and by this contribute to the sustainable manufacturing industries development in the sense of resource efficiency in North Macedonia. By this it will provide a crucial contribution to the preparation of the North Macedonian economy to become a well fitted part of the EU economy, where the basis for it is already existing and well developing further.

UPB and BEIA have both contributed strongly for the emerging and integration of the IoT and IT sector in Romania and the context of the largest industrial center of Romania – the region of Bucharest.

The main goal of EREMI is to introduce students into the resource efficiency in manufacturing, by proactively supporting their understanding of the basics of engineering, system engineering, thermodynamics etc.

### III. CONCLUSION

The higher education courses and programs created and/or extended by the implementation of the EREMI learning contents will become an important and fixed part of the education process in the partner Universities and organisations, and by this will make them sustain in long term and be open and available to anyone willing to access and utilize them.

As previously mentioned, an international Joint Degree Master Program on Resource Efficiency in Manufacturing Industries EREMI are being elaborated during the project duration of EREMI, and afterwards nationally accredited in all 4 partner countries. It is envisaged to address ERASMUS Mundus, as well as the local and regional industrial stakeholders regarding the co-financing of such a large scale undertaking, which will provide added value to the entire set of

relevant stakeholders, by generating internationally trained and experienced interdisciplinary thinking and working engineering professionals, who will shape the sustainable and resource efficient manufacturing industries of tomorrow.

Upon completion of the project, interactive educational resources will be available for use by all stakeholders. In addition, they will be developed and developed so that they can also be used by users outside the system of technical specialties in the system of higher education - training centers, business organizations, enterprises.

The open access digital format as "living documents" of all project outcomes, combined with AR/VR-based learning contents, and live interdisciplinary applied discussions, will allow these to become adapted to the needs of other entities and transferred to new fields and will influence future higher education policies and practices. A guarantee of the sustainability of the project is, besides the online accessible contents, the support of the project stakeholders, expressed through the letters of support and interest at the project start, such as Trakia Economic Zone – the largest industrial park agglomeration in Bulgaria and the Balkans.

### REFERENCES

- [1] Adams M, Comber S. Knowledge transfer for sustainable innovation: a model for academic-industry interaction to improve resource efficiency within SME manufacturers. *Journal of Innovation Management in Small & Medium Enterprises*. 2013 Jan 1;2013:pp 1.
- [2] Kreimeier D, Morlock F, Prinz C, Krückhans B, Bakir DC, Meier H. Holistic learning factories—A concept to train lean management, resource efficiency as well as management and organization improvement skills. *Procedia Cirp*. 2014 Jan 1;17, pp.184-8.
- [3] Higgins M, Grant F, Thompson P. Formative assessment: balancing educational effectiveness and resource efficiency. *Journal for Education in the built Environment*. 2010 Dec 1;5(2), pp. 4-24.
- [4] Seleznev PS, Naumov VN, Zorin VY, Zelenov VI, Tsyplenkov DS, Vasiliev VG. Research and Development of a Unified Methodology for Assessing the Resource Efficiency of International Digital Platform Promotion for E-Learning. *Symmetry*. 2022 Feb 28;14(3), p.497.
- [5] Hernandez-de-Menendez M, Escobar Díaz CA, Morales-Menendez R. Engineering education for smart 4.0 technology: a review. *International Journal on Interactive Design and Manufacturing (IJIDeM)*. 2020 Sep;14(3), p.789-803.
- [6] Oke A, Fernandes FA. Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity*. 2020 Jun;6(2):31.
- [7] Nayak J, Mishra M, Naik B, Swapnarekha H, Cengiz K, Shanmuganathan V. An impact study of COVID-19 on six different industries: Automobile, energy and power, agriculture, education, travel and tourism and consumer electronics. *Expert systems*. 2022 Mar;39(3):e12677.
- [8] BEST: Teaching Energy. [www.iop.org/sep](http://www.iop.org/sep)
- [9] Renna, P.; Materi, S.: A Literature Review of Energy Efficiency and Sustainability in Manufacturing Systems. *Applied Sciences* 2021, 11.