ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT – A STRATEGIC FRAMEWORK FOR UNIVERSITIES

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Abstract—In the context of striving demands for sustainability actions, education came to play an important role. This role has been recognized and emphasized by the United Nations, when it proclaimed the Decade of Education for Sustainable Development (DESD), 2005-2014. Since the beginning of this decade, universities have done a frenetic work to encompass sustainability principles in their core culture. To face this challenge it was important to understand what makes the difference between a traditional university and a sustainable one. Starting from the literature review, this paper offers a conceptual framework for the future development of sustainability in universities. The sustainable development concept will be presented, emphasizing the role of sustainability and outlining those core activities which should be relevant to any university, especially to the engineering one, in its way to respond to pressure of change rising from sustainability demands.

Keywords—Commitment, Higher Education, Sustainable Engineering Education

I. INTRODUCTION

THE concept of sustainable development has acquired worldwide notoriety since 1987, when the Report of the Brundtland Commission, Our Common Future, defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[1]. Emphasizing *intra* and *inter* generational equity, sustainable development has become an ubiquitous subject on governments agenda, sharing the concern equally for economic, social and environmental development. Over the years, many discussions have occurred around what principle should be followed or which steps will be suitable for achieving sustainable development. In 1992 the UN Conference on Environment and Development established in Agenda 21[2] the principles of sustainable development. The commitment for implementing those was reengaged in 2002, at the Rio+10 Summit [3], and in 2012, at recent United Nations Conference on Sustainable Development, Rio+20, when the outcome declaration, "The Future We Want", certified those engagements[4].

Sustainable development brought a new and unique way of understanding the need for globalization and conceptualizing its derivatives aspects, related to social, economic, environmental, political and cultural issues [5]–[7]. Withal, the holistic emphases of sustainable development lead to the emergence of a new and widely known concept: *sustainability* [6]. The comprisal of the two related terms "sustainable development" and "sustainability" could create occasionally the illusion of entire similarity between them, without stressing the differences [8]. In order to highlight this, further on the paper will debate the Education for Sustainable Development (ESD) concept and its framing in sustainable development context, emphasizing the challenge of sustainability in higher education. Moreover, considering the increasing industry's demands for sustainability knowledge among young engineering graduates [9], a strategic framework will be proposed, in order to integrate the sustainability knowledge in the core actions of the universities. In the end of the paper, a case study will be presented in order to highlight the practical efforts of the university to embed sustainability in its core strategy.

II. BUILDING A SUSTAINABLE FUTURE – THE ESD PERSPECTIVE

By resolution 57/254, in January 2005 the United Nations has established the education as being the bottom line of the sustainable development [10]. ESD is not seen as just *education for environment protection*, but its goal is to change people's attitude as consumers, to empower the producers and make them accountable and aware they are responsible for the society and for a durable future.

One of the main objectives of DESD is to integrate the sustainable development in education, at all its levels. This way, the education providers become the main

responsible for developing a sustainable society [11].

There is no standard or universally accepted model of ESD [10; 12] the differences being made depending on priorities and contextual approaches at a local level or at a national level. This fact has been revealed recently when in the second half of DESD the actions for implementation targeted the universities [13]. Thus, at an academic level there have been actions to integrate a concept of sustainable development having a multidisciplinary and interdependent character. Regarded especially as the foundation of the theory, the sustainable development brought into the university education a non-traditional learning [10] component. If one refers to, for example, engineering education, the mix of economic, social, environmental factors in an ethical perspective could lead to the development of new and environmental friendly technologies. Graduates engineers may transfer this way their skills, abilities and ethical values acquired during the years of study into their future workplaces, impacting in a good way community's development and leading to a sustainable future.

Thus, it is reasonable to assume that universities, through the offering of ESD, could play an important role in the evolution of society towards sustainability [9]. Through their mission of offering ESD, the universities are part of the transformation into a sustainable future as well. This transformation, not only from an educational point of view, but also including all its activity aspects, led to the creation of a new concept, the *sustainable university* [14].

A. The Sustainable University – between sustainability and sustainable development

In order to be able to understand the meaning of sustainable university, it should be clarified what *sustainability* means and what are the boundaries between sustainability and sustainable development. According to the definition given by the Brundtland Commission [1], there is no doubt in understanding the concept of sustainable development. On the other side, when one talks about *sustainability* and *sustainable "something"* there are often misunderstandings, both in debate and literature, regarding the correct meaning [15].

Foster [16] defines sustainability as being the "permanent adaptive responsiveness to a permanently changing, ever-emergent set of circumstances". Atkinson and Wade [17] argue that "sustainability is about social change", while Sterling [15] creates an overview, attempting to delineate the two concepts: "sustainability is about securing economic viability, social coherence and ecological integrity at local to global scales – where these system conditions are seen as deeply co-dependent rather than as separate dynamics. Sustainable development is the journey towards these conditions." Making an analogy between the two keywords they consider as being linked to sustainable development: "necessity and limitation", Barsan and Barsan [18]

discuss about sustainability as the necessity for development in an ethical way.

Therefore, it can be asserted that sustainability refers to the way (How? With what? Who?) in which the actions conducting to sustainable development are taken. Inferring to the academic level, sustainability in the universities could be summarized as being the actions taken for its embedment in curriculum, campus (emphasizing the environmental aspects through protective actions), basically in the entire institutional culture, allowing an influence on the university's relationships with its environs and thus contributing to society efforts towards sustainable development.

In order to understand what the sustainable university is, it must be established its role played in society, its connections with the society and what are those actions that will contribute to sustainable development.

B. The role of the sustainable university – a contribution to sustainable development of the society

As it has been shown, the DESD supported the efforts and contributed to the alignment of policies and educational guidelines with the sustainability demands. However, it is the duty of higher education to continue this undertaking.

As all organizations, the universities activate in direct collaboration with their stakeholders, although it can be asserted that their fundamental role is to provide education. Hence, the means in which universities manage to provide the future graduates with the necessary knowledge to create a sustainable future are of great importance [15].

Many skeptics might wonder why universities are responsible and if not their responsibility burden is overestimated. Many could claim the focus should be on the industry activities and that universities are not the big polluters, don't have major economical stakes and are not the biggest employers either.

All the above are true, however the universities must not be looked at as standalone entities, but rather as *bottom line providers* for a sustainable future.

According to the Organization for Economic Co-operation and Development (OECD) [19] there are more than 17,000 universities in the world in which approximately 135 million students are studying. Moreover, as claimed by Maslen [20] till 2025 this number could be double.

Although only two percent of the global population followed a higher education, in politics and industry more than eighty percent of the decision-makers are university graduates [21]. Hence, all the future graduates are the ones who will work and lead the industry. In accordance with the education provided nowadays by universities, students' knowledge, skills, abilities and ethical values will lead to a sustainable, or on the contrary, unsustainable development.

The fact that education is the right path to a sustainable

future is stated by the UNESCO report: "Sustainable development cannot be achieved by technological solutions, political regulation or financial instruments alone. Achieving sustainable development requires a change in the way we think and act, and consequently a transition to sustainable lifestyles, consumption and production patterns. Only education and learning at all levels and in all social contexts can bring about this critical change."[22]

Thereby, the pathways through which the sustainable education could be provided remain the rightful attributes of the universities and the greatest challenge for them to acquire and maintain. It is only normal that one can state a university could contribute fully to a sustainable development only by becoming sustainable itself, in other words becoming a *sustainable university*.

The role of a sustainable university is to embed in its research activities, curriculum, campus management, governance, community links, those ideas, concepts and values which come into play when pursuing global ideals of sustainable development.

The key components of sustainability in universities are presented in fig. 1.
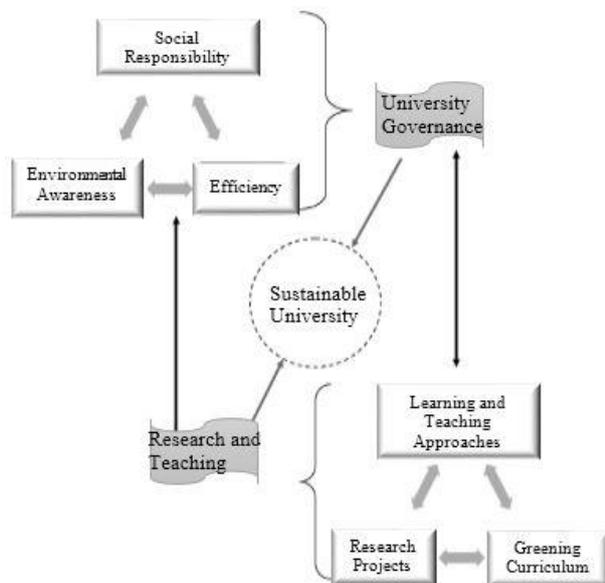

Fig. 1. The key components of a sustainable university

University Governance and Research and Teaching are the main components, interrelated and interdependent.

The governance refers to university's actions as a pillar for society, to its responsibility towards environment as well as to the efficiency of those actions, both internally and externally.

Actions as the greening campus, contribution to community development, volunteering actions, reduction of carbon footprint of the university, internal ethic code, internal standards, and elaboration of sustainability reports, all are part of the core being of university governance. Even though these attempts of the university represent in itself a great challenge, they bring a significant contribution to the economic and environmental development of the society.

At the same time, the university governance is in tight correlation with activities aiming at research and teaching because these have to ensure students are getting through the teaching process, the knowledge and abilities required for a sustainable development in accordance with the requirements of the well-being of people and planet.

By drawing attention over the necessity to change the educational paradigm, Orr stated: "those who contribute to exploiting poor communities and the earth's ecosystems are those who have BAs, MBAs, MScs and PhDs and not the "ignorant" poor from the South" [23].

Research and teaching remain therefore the sensitive points of the university sustainability; one could talk even of a "sustainability deficit" in regards to academic curriculum.

By analyzing the industry need for sustainability knowledge a great demand and deficit of this knowledge was recognized among the recently employed graduates [9], [15].

In a report of Business in the Community, the companies recognize in proportion of ninety percent that leadership skills are mandatory for developing sustainable businesses and more than eighty percent believe that higher education is directly responsible for doing more in order to provide these skills [24].

In order to fill in the gaps between industry demands and knowledge provided, universities should:

- Approach actual environmental, social, economic and political problems within their research
- Include sustainability notions (and others related like, for example, business ethic or social responsibility) within actual research or teaching areas, or as a standalone teaching major
- Find method to stimulate creative thinking and students' ethical personality
- Develop students' capacity to identify, understand, evaluate and adopt principles which lead to sustainability
- To gain capacity to apply theoretical knowledge into practice, in order to act responsibly
- To involve students in social actions within the local communities by developing in this way awareness of social implication and non-curriculum activities
- Develop close connections with businesses and industries from local areas, thus offering internships or preparation stages, in other words, real-world learning opportunities for students.

For the future engineers education is vital to understand and promote sustainability principles. Thus, changing the university strategy must be innovating, professionally managed, proactive, and leading to a

sustainable university.

III. THE UNIVERSITY OF EDINBURGH – STEPS TOWARDS A SUSTAINABLE UNIVERSITY

In analyzing the sustainability implementation method in the University of Edinburgh [15], the central aspects of the sustainability concept are emphasized through institutional undertakings, as contributions to sustainable development. Considering the three aspects of the sustainable development, economic, social and environmental, the University of Edinburgh focused on the introduction of sustainability measures through curriculum, campus management and university culture. Based on the principles of ESD, the sustainability measures were made part of the university's core strategy.

The introduction of the sustainability concept is a great change in any large educational institution. In order to address the challenge, an institution has to establish *clarity of purpose*, meaning the staff and students, acting together as a united community have to agree and understand the difficulties, document the intended measures in the institution's strategy plans and guidelines. It is also beneficial to acknowledge that the process of change can offer important group and personal learning opportunities for students and staff.

Looking at the first steps of sustainability implementation at the University of Edinburgh, it is established the context in which the university started its first initiatives of *social responsibility* and *environmental awareness* as means to become more efficient and attractive globally. These actions were included in the strategic plans which are in synchronization with the national and international agreements on sustainability.

The university has therefore established clear *governance* and the guiding principles started to be applied first in *the research and teaching approaches*, keeping always as central point the students' interests and their relationships with the campus administration, curriculum and other communities outside the university.

A. *The context analysis*

The University of Edinburgh is the biggest university in Scotland and fourth in the UK, with over 29,000 students and 8,000 teaching, research and support staff (3,300 of whom are academic) engaged in over 101 undergraduate and 259 postgraduate programs with an annual budget of £650 million. The university is a top international research institution as well. Main areas where sustainability issues are addressed are engineering and social sciences. Considering this challenging context, the University has started to make a priority since 1990 out of sustainability by including it in its strategic plans.

Thereby, in 1990s the University started an initiative called "Curriculum Greening". It was an attempt to introduce sustainability into many subject areas across the university.

As for any other large institution, implementing sustainability was problematic for the University of Edinburgh as it interfaces with personal beliefs and values. The university's governance has been based in a significant degree on the Scottish government policies which made sustainability one of its main strategic objectives through actions like reduction of carbon emissions, policy development aimed at social inequality within Scottish society and development of renewable energy capabilities in order for Scotland to become a world leader in supporting its own energy demands through sustainable sources and thus become more competitive economically on international markets.

All these commitments will need to be supported by higher education institutions and the University of Edinburgh took this into account through several initiatives.

First, it took place the elaboration of guiding principles through its 2008-2012 and 2012-2016 Strategic Plans. Moreover, a strategy document "Social Responsibility and Sustainability Strategy 2010-2020" was developed. The strategy document presents a mission to make a "significant, sustainable and socially responsible contribution to Scotland, UK and the world, promoting health and economic and cultural wellbeing" [25]. In parallel, the University adhered to international - Universitas21 (2009) *Statement on Sustainability,* and national - Universities UK (2010) *Statement of intent,* agreements on sustainable development [15] [26].

B. *The campus (environmental dimension)*

Among the steps made by the University of Edinburgh, the involvement of students association in the practical implementation of sustainability was one of the most important ones, particularly through estate management and procurement functions. Their main objective was to increase efficiency of resource utilization. As Sommervell states, promoting "a more sustainable university and reducing the university's environmental and carbon footprint, involves making the most effective use of natural resources, promoting whole life costing to contain utility costs, supporting continuous improvements in campus infrastructure, contributing to the university's missions of promoting excellence in research and teaching, and liaising with others such as Scottish Environment Protection Agency to promote best practices on campus" [27]. Such undertaken actions have in turn brought significant financial benefits which were communicated and advertised within the university but also within city communities.

As a result, the university became the first accredited Scotland's Fairtrade University in 2004 and an initiative towards sustainable procurement has started. A series of corporate guidelines supports the "procurement of goods and services to ensure efficiency and effectiveness, while minimizing social and environmental risks [28]. It is therefore clear that the procurement staff follow a sustainable procurement process and adopted the "whole-life costing to deliver low-carbon and low-maintenance solutions" [15].

C. The curriculum – the ESD dimension in research and teaching

It is recognized the fact that even when a university is challenged by the great change towards sustainability, it is important to acknowledge an important advantage: group and personal related opportunities for students and staff [12] [14]. Both stakeholders are aware of the benefits that could come with sustainability and promote adjustments of the curriculum to accommodate cross-disciplinary education in subjects related to sustainability to meet a "growing market for graduate employment in corporate social responsibility, environmental education, environmental management, environmental auditing, environmental politics, risk management and sustainable citizenship" [15].

It is emphasized the students' recognition and pro-activeness towards creating new interdisciplinary programmes which will allow them to succeed in their studies and later in their employability. At the same time it is showed the normal tension which can appear "between the need for academic freedom and student choice" [15] when trying to include sustainability in the curriculum. The University of Edinburgh has addressed this by interactions and discussions with the students when curriculum is decided. As a result, the sustainability has not become compulsory in all courses, but options are given and flexibility is possible.

In the Edinburgh case such changes occurred and are planned to occur at all levels of academic studies: undergraduate, master and doctoral programmes and partnerships are developed to cover areas such are for example: Environmental Sustainability; Environment and Development; Culture, Ethics and Environment; Engineering Ethics, Outdoor Environmental and Sustainability Education; Carbon Management; Carbon Finance.

The great number of programmes increased flexible study choices and distance learning to reduce travel (saving CO_2 emissions and costs). At the same time the relationships between different programmes are expected to develop as students are more and more interested to take cross-disciplinary courses as options. It is proven therefore that the students are fully engaged in curriculum development.

D. The communities (social dimension/social responsibility)

After underlining the sustainability actions within campus as an element of implementation of sustainability within the university, further on the attention is focused on the impact the students make by transferring the knowledge gained from the sustainable university to their working places and wider communities in which they will live and develop. A great importance is given to the collaboration between students and academic staff and to the immediate benefit the public can have from both parties highly educated and aware of the sustainability impacts.

Students and staff alike are directly involving into volunteering activities, promote recycling, "sustainable travel choices, conservation of energy and generally being good neighbors" [15]. It is recognized the impact communities can have on a long-term on the economic, cultural and social development of the local areas and pointed out that university's representatives establish linkages with external stakeholders in order to exchange knowledge and latest innovations relating to sustainability.

An example is given in relation to the above aspect of collaboration between researchers and communities: engineering is a highly impacted domain by sustainability related developments (carbon capture, storage and innovative energy developments) and thus is likely to have a great impact on resources and energy utilization within industrial processes. A constructive discussion between universities, business and social communities is widely facilitated as the engineers can directly impact on how the people live, for example architects, construction engineers and chemists.

E. The steps forward

A very clear message is given by the University of Edinburgh in relation to the challenges to become a sustainable university: "before institutional change can be stimulated, there must be a sense of community engagement in this process, stimulating both acceptance of change and commitment to facilitating it by all members of the community" [15].

After starting from written policies and embedding them in the long-term strategic plans, the university continues to encourage critical thinking and debating through various groups and commissions, in its efforts towards sustainability.

Future activities refer to responding to positive political circumstances like United Nations DESD, interest in green jobs and global challenges at the same time with promoting dialogue and negotiations and "working collaboratively with staff, students and other communities towards a participative decision making"[15] [25] [29].

The University of Edinburgh had the courage to face the challenges of sustainability implementation through undertaken actions bringing a continuous contribution to its social, economic and environmental security and thus becoming a leading example in the academic world.

IV. CONCLUSION

The implementation of ESD in universities is a complex undertaking, long lasting, with implications at all academic levels, staff, professors and students, and with direct connection in community.

This academic transformation involves key processes from the core strategy of universities. In the last years, more and more changes took place within the technical universities, where new sustainable development courses were introduced in curriculums, and sustainability issues were approached in a series of research programs,

especially in the energy and climate change areas [10], [13]-[15].

The universities must become aware that the change of learning and teaching methods in accordance with new demands of the industry is mandatory.

In order to achieve this, a tight connection with universities' stakeholders must be kept, while the two key components of sustainable university must be in permanent contact with *outside demands* from environment and society.

Although orientation towards sustainability is a process which needs manifold commitment, the shift of traditional engineering education towards engineering education for sustainable development is the key to a sustainable future and it must be accomplished.

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