ENGINEERING IN SUSTAINABLE DEVELOPMENT BY TECNOLOGICO DE MONTERREY: AN INNOVATIVE ACADEMIC PROGRAM IN SUSTAINABILITY FOR MEXICO

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Abstract

Nowadays climate change is an emerging crisis that has triggered noticeable problems within our planet including high CO2 concentrations, extreme temperatures, sea level increase, threat of wildlife and ecosystem modifications. Specifically in Mexico since the creation of the Ministry of Environment and Natural Resources, the country has been aware that Mexico suffers from rough environmental issues: energy transition to renewables still has a long way to go because of the oil industry historical coverage; CO2 emissions does not present a downward behaviour; water and waste management suffer from lack of regulations and proper techniques for its industrial exploitation; and it is vulnerable to unpredictable conditions for agriculture, ocean acidification, disease spread, natural disasters, and poor air quality. These negative environmental impacts have originated the necessity to incorporate innovative education. Within Mexico, different courses in the subject have emerged. There are currently 87 institutions where degree programs in Environmental Engineering is taught. Some examples are the largest public universities in the country. However, within these institutions, there is no academic program that includes social, environmental and economic aspects at the same time since each institution gives an approach according to its interests. Tecnológico de Monterrey is the exception. The engineering academic program in sustainable development trains engineers to solve problems from a social, environmental and economic perspective; looking for a balance between the three pillars of sustainability and thereby having the tools to achieve the UN Sustainable Development Goals. Furthermore, this academic program contemplates the whole panorama combining three engineering (chemical, environmental and electric), as well as involving the students with enterprises that are looking to incorporate sustainability in their processes and making their practices greener. Additionally, the institution counts with appropriate infrastructure and laboratories for professional practices along with a complete syllabus that goes from fundamentals of process, energy and thermal engineering to principles of sustainability, business and ecosystems, regulations and involvement with stakeholders.

Keywords: Renewable Energy, Sustainable Development Goals, Pillars of Sustainability, Innovative Education, Sustainability in Mexico,

1. ABBREVIATIONS AND ACRONYMS

ANP: Natural Protected Areas (for its acronym in spanish)
CO2: Carbon Dioxide
CONABIO: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (for its acronym in spanish)
CH4: Methane
Gg: Giga grams
GHG: Greenhouse Gas
SD: Sustainable Development
SDGs: Sustainable Development Goals
SEMARNAT: Ministry of Environment and Natural Resources (for its acronym in spanish)
HDI: Human Development Index
HFC: Hydro-Fluoro Carbons
IDH: Índice de Desarrollo Humano (for its acronym in spanish)
IDS: Sustainable Development Engineer (for its acronym in spanish)

INEGI: National Institute of Statistic and Geography (for its acronym in Spanish)
ITESM: Instituto Tecnológico y de Estudios Superiores de Monterrey (for its acronym in Spanish)
NO2: Nitrogen Dioxide
PACE: Action Programs for Species Conservation (for its acronym in Spanish)
PFC: Per-Fluoro Carbons
PPM: Parts per million
SF6: Sulfur hexafluoride
UMA:Units for Wildlife Conservation (for its acronym in Spanish)
UN: United Nations
ZMVM: Metropolitan Zone of the Valley of Mexico (for its acronym in Spanish)

2. INTRODUCTION

Since the industrial revolution, man created processes that have made our lifestyle more efficient, quick and cheap; resulting in allowing humankind to be able to manufacture in chain and transport products and people through long distances, allowing there to be a wide variety of goods and services that before weren't possible. This was made possible, in part, by the development of steam machines, that burned coal to extract energy from the heat of reaction that could generate an engine and therefore mechanical work, but the combustion reaction had as an effect the liberation of carbon dioxide principally as a byproduct. The problem with this compound is that it has Greenhouse effects, which means that it has the faculty of storing warmth within the atmosphere, elevating the average global temperature.

Later on, oil took over the energy industry, becoming the main fuel used to generate mechanical work in its various forms, like different types of gasoline. Weather it is moving cars by burning gasoline, giving planes thrust with the energy of combustion, or generating the amounts of electricity that big cities consume. The effects of this have increased the mean temperature of the earth by 0.6ºC, causing climate change, natural disasters and many climate refugees. Because of these effects, the total surface of tundra is decreasing, in consequence the number of deserts increases, and more forests are catching fire. [2]

In 2015, more than 150 worldwide leaders went to the United Nations summit on sustainable development in New York, where an agenda was approved and adopted by the 193 member states of the UN. This agenda includes 7 objectives that stand on the three pillars of sustainable development and sets goals for the year 2030. These goals are ambitious and hard, yet realistic if implemented with efficiency by professionals around the world. [1]

A lack of consciousness and caring gas led to severe setbacks to fulfill the agenda on time, like bigoted rulers that burn jungles to harvest livestock or that deny climate change. The Mexican leaders, for example are investing in oil plants instead of harvesting the sun in its big desserts or the wind in its isthmus, the economic and social matters are also being neglected and there is a niche for development in sustainability all along the country, so that professionals in the matter can work to achieve the SDG's and in consequence improve Mexico's economy, social fabric and environmental action, permeating to other Latin American countries and increasing the chances to fulfill the agenda in a determined period of time at a global scale. [7]

3. RESEARCH METHODOLOGY

For the following research, a qualitative method was carried out, for which, techniques such as interviews, focus groups and existing data were used.

135 alumni from the last semesters of the academic program (7th to 9th semester) were interviewed. They were asked to answer the following questions: What is the meaning of being an IDS in Mexico? what subjects from the syllabus had the highest impact to solve the issues Mexico has in relation to environment? and on which SDGs they believed the academic program had the highest impacts? With the answers given, the information was sorted and grouped in blocks of similar answers to carry the analysis out. Therefore, to analyze the information collected from the techniques of the qualitative method, a Likert scale of five points divided into strongly disagree,

disagree, undecided, agree and strongly agree, was used in order to allow the students and professors to express objectively their opinion within the statements.

From the 135 interviewed alumni, 48 attended 4 different sessions of focus groups where subjects like “The impact of an IDS on the SDGs at the UN”, “The most impactful environmental, economic and social issues that Mexico currently faces”, “The importance of an IDS in Mexico” and “The importance of the SDGs from an IDS’s perspective” were discussed. From what was heard in these sessions, which were recorded for further analysis, important details were gathered to deepen on them. The analysis was based on the most frequently repeated words and opinions, as well as blocks of agreement and disagreement.

Similarly, information from organizations dedicated to sustainability in Mexico was gathered, such as SEMARNAT and CONABIO. As well as key institutions for sustainability education such as ITESM.

4. DEVELOPMENT

4.1 What is a sustainable development engineer?

Nowadays, both industry and society demand more actions, solutions and innovations to improve the quality of life of present and future generations, based on the development of new technologies and strategies that reduce the impact. that the activities of human beings have on the planet. This has prompted the emergence of new specialties in the engineering sector as is the case of the academic program of sustainable development engineering.

A sustainable development engineer has the ability to design energy processes of different scales based on sustainability principles, as well as design innovative corporate sustainability strategies, using cutting-edge methodologies. It also has the ability to improve production processes throughout its value chain, favoring the efficient use of natural and energy resources, it can evaluate the availability and restitution of natural resources, generating alternatives of exploitation that favor the creation of business models. In addition to this, it has the ability to analyze, evaluate and solve multidisciplinary problems related to the sustainable use of natural resources, the various sources of energy and their impact on society using cutting-edge technological tools and methodologies; Also knows the current legislation and public policies and incentives to propose integral solutions considering sustainable technologies and materials. [4]

The above is achieved through a syllabus in which three engineering are combined: electrical, chemical and environmental, in addition to never neglecting the economic and social part, and always working on real projects with training partners that give the student a greater vision of what is currently lived in the workplace. At the same time, it seeks to train graduates for the fulfillment of the seventeen Sustainable Development Goals (SDGs).

4.1.1 IDS TEC 21

Today the IDS 11 model has undergone certain changes to become the IDS TEC 21 model, the degree is now part of the area of Engineering, Bioengineering and Chemical Processes, where there are also academic programs such as Food Engineering, Agrifood Biosystems Engineering, Biotechnology Engineering and Chemical Engineering. Likewise, it now has three stages: Exploration, Focus and Specialization. In the exploration stage, undergraduates have the possibility to choose the various disciplines of the area in which they entered. For the focus stage, they delve deeper into the academic program where they begin to face more specific sustainability challenges. Finally, in the specialization stage, the pupils personalize the program according to their interests and plans. Also, during this last semester, the students can take the *Semestre TEC*, which allow them to develop specific skills of the engineer through experiences abroad, professional practices inside and outside Mexico and even research stays.

Now there are blocks, in which challenges applied to reality are solved collaboratively, where students are supported by a group of teachers who guide learning, in addition to assessing competencies at the end of the challenge. Practically the student receives classes for a certain number of weeks to later start the *Semana TEC*, a week in which what is learned in the classroom is put into practice through challenges. These types of challenges challenge students to observe what the working world really is, map situations, diagnose problems, reflect, dialogue and confront ideas about theories and techniques to solve these problems, as well as to experiment, design and produce prototypes and solutions. , within a reflexive and applicative dynamic in which they can take risks, make mistakes and make adjustments to achieve the objective [5].

Table 1. shows the most relevant courses of the career according to the TEC 21 model. However, as mentioned above, each of the courses are indispensable for the training of an engineer in sustainable development. The complete syllabus is found on the ITESM website.

Table 1. Part of the syllabus of IDS TEC 21

Area	Name of the course
Exploration	
Focus	Evaluation of Natural Capital and Sustainability Principles
	Implementation of Resource Management Programs
	Application of the Principles of Energy Efficiency
	Analysis of Processes and Circular Economy
Specialization	Innovation of Corporate Sustainability Models
	Design of Corporate Sustainability Strategies
	Advanced Sizing and Monitoring of Energy Processes
	Innovation of the Processes in Your Value Chain
	Improvement of Productive Processes Applying Principles of Circular Economy
	Design and Implementation of Energy Sustainability Models
General Education	Elective Course Ethics and Citizenship
Elective Courses	

4.3 Why does Mexico need sustainable development engineers?

Nowadays, Mexico City suffers an environmental crisis due to lack of action plans that fulfill the needs of our country in a sustainable way. According to a 2012 Environmental Situation Report in Mexico by SEMARNAT, Mexico contemplates seven factors that are key to solving the environmental crisis [7]:

4.3.1 Population and environment

Mexico has maintained its 1.2% annual growth rate throughout the century and has an advanced phase of demographic transition since mortality and fertility rates are low. Although the HDI in average along the country is 0.77 which lays in high levels, the marginalization within indigenous locations speaks differently. The average IDH in these towns it’s found between 0.29 and 0.32, a very close index to countries like Niger and Democratic Republic of the Congo. Furthermore around 741 and 35 municipalities in Mexico are in poverty and extreme poverty respectively. Finally, it is estimated that more than 550,000 people in Mexico have migrated due to environmental disasters (low temperatures, tropical cyclones, floods, hailstorms, droughts, tornadoes) [6]

4.3.2 Terrestrial ecosystems

According to INEGI Potential Primary Vegetation Chart, between 1976 and 2009 Mexico has lost the equivalent to 13.22 millions hectares of natural vegetation and it is estimated that it occurs at an annual rate of 1.208 millions hectares. This represents almost 9% of Mexico's total vegetation surface. Furthermore, between 2003 and 2006 the national average CO2 emissions associated with the change in forest land use increased to 7,189 Gg of CO2. [6]

4.3.3 Soils

Soil degradation in Mexico is affected by four main phenomena: water erosion, wind erosion, chemical degradation and physical degradation. Along the country 22.73 million ha, 18.12 million ha, 34.04 million ha and 10.84 million ha suffer from this phenomena, respectively. These conditions lead to 88%-95.5% loss of surface soil, 11.7% of ground deformation, 4% decreased water availability and even 25% of loss of productive function; all of this translating in hindering food safety all over the country. [6]

4.3.4 Biodiversity

Although Mexico is a megadiverse country it has lost around 30% of its original diversity [3]; this, as a consequence of the greater demand for space, food, fresh water and energy required by modern societies along with invasive species, climate change and extinction. Since there are more than 30 considered species for the elaboration of Action Programs for Species Conservation (PACE) new projects have emerged. Up until 2011, more than 174 Natural Protected Areas (ANP) and 10,855 Management Units for Wildlife Conservation (UMA) has been created. [6]

4.3.5 Atmosphere

Nowadays in the ZMVM there has been considerable amounts of different emissions up to 2011: 1.5 PPM of CO, 0.005 PPM of SO2, 0.05 PPM of NO2, and 28 $\mu g/m^3$ of PM 2.5. Additionally, pH value has diminished over the years having registered values between 4.0 and 4.5. GHG has increased more than 33.4% since 1990 in 748 million tons of CO2 equivalent. Among the industries that stand out the most are energy, agriculture, waste, changes in land use and forestry, which have never had a downward behavior. The GHGs with the most impact are CO2, CH4, SF6, HFC, PFC and NO2. Likewise, in the actual day there are more than 400 PPM of CO2 concentration which makes Mexico count with an average annual temperature of 0.7 ºC, increase the average intensity of tropical cyclones between 2 and 11%, annual increases of 4.23 and 3.28 millimeters at sea level, and loss of biodiversity in 30%. [6]

4.3.6 Water

Water availability in Mexico is relatively greater than most european countries (>460 km^3), but behind the United States, Canada and Brazil. However, the annual availability per capita which lays around 1700 m^3 puts Mexico in a water stress situation with a 2000% pressure point. Furthermore, recurring extreme weather events such as droughts or excessive use of water for food production makes the situation even more difficult. In 2013 alone, more than one million hectares and 13 thousand head of cattle were lost in five states of the country and the amount of water destined to produce only one kilo of meat is 16 thousand liters. [6]

4.3.7 Waste

Although Mexico counts with more than 30 norms that regulate urban solid waste and hazardous wastes, it faces environmental risks within nine sectors: energy generation, hazardous wastes, *maquiladoras*, LP gas, chemical, food and beverages, fuel, and metallurgical miner. Moreover, between 2008 and 2011 more than 514 environmental emergencies were reported having as responsibles hydrocarbons, diesel and acids. [6]

4.4 The SDG's from the perspective of an IDS

Sustainable Development Engineering is an academic program that impacts directly in all of the 17 SDGs. Taking a previous look at sections 3.1.1. and 3.1.2. exampling the evolution of the syllabus, there have always existed a direct correlation between subjects of IDS with one or more SDGs. For example, "Affordable and clean energy" SDG considers necessary to ensure access to energy for all, while "Responsible consumption and production" SDG contemplates more the part of sustainable consumption and production patterns [7]; although specialized sectors could attack the problem directly but separately, a Sustainable Development Engineer manages to provide a solution for both concerns as a result of its formation. Just as Table 2 depicts, the versatility of the syllabus allows an engineer of this kind to meet the needs of the 17 Sustainable Development Goals in an integral way. Every project in which an IDS is involved, revolves around SDGs; these projects are created to fulfill partially or totally the global needs.

Table 2. Correlation between SDGs and Sustainable Development Engineering subjects

SDGs	IDS related subjects	SDGs	IDS related subjects
1 NO POVERTY	· Social Responsibility and Corporate Sustainability · Natural Resources Management and Climate Change · Entrepreneurship	10 REDUCED INEQUALITIES	· Social Responsibility and Corporate Sustainability · Organizational Behavior and Human Talent Development · Ethics, Self and Society
2 ZERO HUNGER	· Social Responsibility and Corporate Sustainability · Natural Resources Management and Climate Change · Entrepreneurship	11 SUSTAINABLE CITIES AND COMMUNITIES	· Industrial Ecology · Eco-efficiency and Sustainable Processes · Natural Resources Management and Climate Change
3 GOOD HEALTH AND WELL-BEING	· Social Responsibility and Corporate Sustainability · Natural Resources Management and Climate Change · Entrepreneurship	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	· Industrial Ecology · Eco-efficiency and Sustainable Processes · Natural Resources Management and Climate Change
4 QUALITY EDUCATION	· Social Responsibility and Corporate Sustainability · Citizenship · Applied Ethics	13 CLIMATE ACTION	· Natural Resources Management and Climate Change · Social Responsibility and Corporate Sustainability · Businesses and Ecosystems Conservation
5 GENDER EQUALITY	· Organizational Behavior and Human Talent Development · Entrepreneurship · Social Responsibility and Corporate Sustainability	14 LIFE BELOW WATER	· Ecosystems and Biodiversity · Natural Resources Management and Climate Change · Businesses and Ecosystems Conservation
6 CLEAN WATER AND SANITATION	· Sustainable Water Use I · Sustainable Water Use II	15 LIFE ON LAND	· Ecosystems and Biodiversity · Natural Resources Management and Climate Change · Businesses and Ecosystems Conservation

7 AFFORDABLE AND CLEAN ENERGY	· Alternative Energy · Technologies for the Efficient use of Thermal and Electric Energy · Energy Project Management · Energy Distribution Systems	16 PEACE, JUSTICE AND STRONG INSTITUTIONS	· Businesses and Ecosystems Conservation · Negotiation and Conflict Management · Applied Ethics · Citizenship
8 DECENT WORK AND ECONOMIC GROWTH	· Social Responsibility and Corporate Sustainability · Economy to Business Creation · Project Evaluation and Management	17 PARTNERSHIPS FOR THE GOALS	· Social Responsibility and Corporate Sustainability · Negotiation and Conflict Management · Applied Ethics · Citizenship
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	· Industrial Ecology · Eco-efficiency and Sustainable Processes · Social Responsibility and Corporate Sustainability		

5. CONCLUSIONS

The qualitative research method showed that 94% of students and professors believe that IDS is an academic program that effectively contributes to generating quality graduates to combat the 17 SDGs established by the UN. In addition, around 80% consider that the subjects with the greatest impact on these are "Social Responsibility and Corporate Sustainability", “Natural Resources Management and Climate Change” and “Eco-efficiency and Sustainable Processes” which coincide with Table 3. as the courses with highest incidence in each SDG. As well, around 98.7% of the interviews people said that an IDS is someone who is capable of solving problems from a social, economic an environmental perspective applying engineering skills and knowledge.

Although research on climate change is growing and backed up by science, there are people who promote personal agendas denying its existence, hence it is the responsibility of professionals in the subject to promote the science throughout other fields, building awareness and taking effective action from the industrial, political and business spheres, reaching the highest impact on sustainability and thus letting humankind to have the least impact on the global environment.

As the UN states: “More people around the world are living better lives compared to just a decade ago. More people have access to better healthcare, decent work, and education than ever before. But inequalities and climate change are threatening to undo the gains. Investment in inclusive and sustainable economies can unleash significant opportunities for shared prosperity. And the political, technological and financial solutions are within reach. But much greater leadership and rapid, unprecedented changes are needed to align these levers of change with sustainable development objectives.” [7]. It is time to take action, and what better motivation to keep training people, like an IDS, that fulfill the needs of SDGs.

Training professionals who have the ability to design, improve, evaluate, and analyze from a perspective focused on the three pillars of sustainability is very important, since a rational and efficient administration and care of resources is needed with the objective that it is possible to improve the well-being of today's society without compromising the quality of life of future generations. However, it is also essential that, in general, all professionals have a vision to promote socio-ecological conservation and global sustainability through their profession, since the collaboration of all, academia, governments and nonprofit organizations is necessary to work in set to meet the Seventeen Sustainable Development Goals.

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