ROLE OF SCIENCE AND TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

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ABSTRACT

Sustainable development should be a prerequisite criteria in evaluating the objectives and outcomes for any project in any field of life. However confusion exists on the definition of sustainability in the literature and in the society at large and various criteria, actors, goals and other items have been unsystematically mixed in a pot without a clear distinction. Furthermore the majority of products used so frequently in all aspects of modern life today are products of science, technology and engineering. Most of them originate from metals and materials extraction and processing industries. Despite this, confusion again exists in the perception of the society about the general role of science, technology and engineering on sustainable development. Science and technology is sometimes not even considered as a solution provider for sustainable development.

This plenary paper clarifies this confusion by making a clear distinction between criteria, actors and goals of sustainable development and provides a new sustainability framework through a new graphical representation. This new framework is used to present and interpret the author's own modified central paradigm of materials science and engineering along with its recyclability/reutilization dimension. Recycling versus waste, linearity versus circularity and automation versus manual work are analyzed in terms of their advantages and disadvantages in the light of the new framework concluding that recycling, circularity and automation are genuine sustainable activities.

The role of science/technology, governance & management and education & civil society are analyzed as three composite actors or pillars of sustainability. It is concluded that the winning formula is a close and strong cooperation between them in equal levels and as equal partners if science and technology is kept first in the order of actions. This is because science and technology has the first word in diagnosis and the last word as in solving issues related to long-term sustainable development.

Keywords: sustainability, sustainable development, sustainability criteria, sustainability pillars, modified paradigm of materials science and engineering, recycling, reuse, automation, role of science and engineering, role of government and management, role of education and civil society, metallurgy, mineral materials processing, engineering, environment, technologies, scientists and engineers' role.

SUSTAINABLE DEVELOPMENT

Sustainable development is generally defined as using the earth resources in such a way that meets the human needs at present times without prohibiting future generations of the same opportunity. The 1987 Brundtland Report [1] was the first major international engagement in this direction.

In fact, sustainable development was first graphically defined as three intersecting spheres by the economist René Passet in 1979 [2] and modernized graphically in 2006 [3]. Each sphere respectively represents development in Environment, Economy and Social point of view. The common intersection of the three spheres represent the sustainable development. It is a simple and powerful definition of sustainability. Based on this definition, any activity in life has to simultaneously fulfill these 3 criteria in order to be sustainable.

There have been attempts to expand this definition to include culture and politics [4-5], institutions or governance [6] in a loose definition of sustainable development. To our opinion, this is where the confusion starts. The criteria, the actors, the goals, have been unsystematically mixed without a clear distinction. The original definition of sustainable development has 3 intersection criteria: environmental protection, economic development and social development. In order to achieve the sustainable development these three **criteria** need to be fulfilled simultaneously. Additional inclusions of culture, politics, governance, institutions in the criteria of definition is illogical. Culture is part of social development, already one of the criteria of the sustainable development. Politics, government and institutions are **actors** that with their actions, laws, regulations etc. can achieve or undermine the sustainable development. It is extremely important to have a clear distinction between the definition of sustainable development as a set of criteria to be achieved and the actors that can make possible achieving or undermining these criteria. The following is the clarity that we need:

The Sustainable Development Definition/**criteria** are:

- Environmental protection
- Economic development
- Social development

All actions or activities from any field are sustainable if they simultaneously fulfill these three criteria.

Actors that with their actions can achieve or undermine the sustainable development are:

- Science, Technology and Industrial Practice
- Governance (executive, legislative, juridical) and Management
- Education and Civil Society

The above may be alternatively called **pillars** of sustainability **if** they have as a goal to fulfill simultaneously the three aforementioned criteria.

Following this new concept and classification, Figure 1 shows a newly designed schema of the sustainability framework with the 3 criteria and 3 pillars of sustainability.

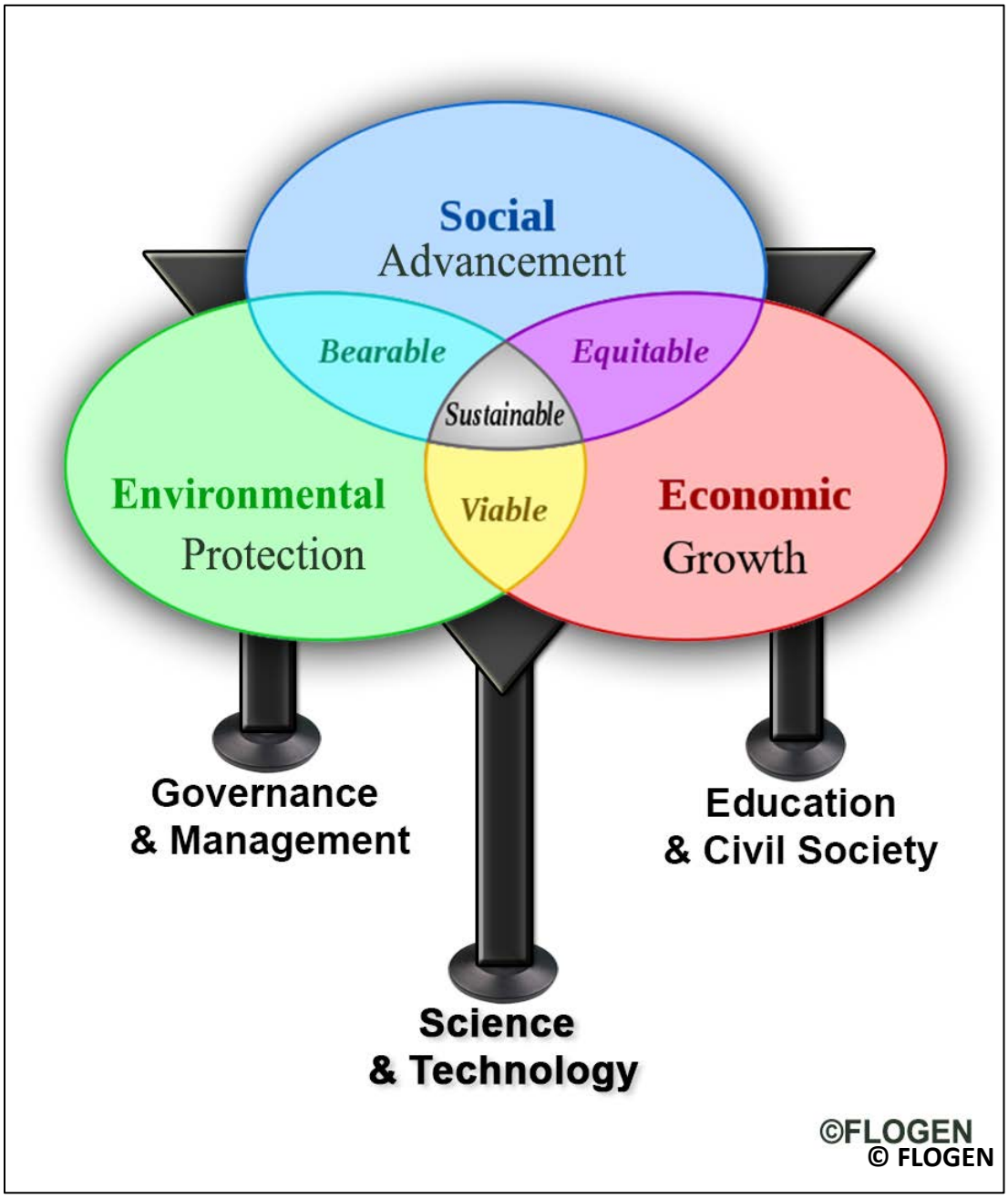

Figure 1 – Pillars/Actors of Sustainable Development in a new Sustainability Framework.

Any force, action or activity in any field, fall in one of these actors/pillars.

Sustainability **goals** are in fact the desired end-results that achieve individually or in group the three criteria of sustainability.

This simple and clear new sustainability framework should be the guiding light for the analysis of several human activities. In this point of view, this article retakes the main ideas and conclusions published recently by the author and interpret them under the new light of the above mentioned sustainability criteria, bringing at the same time some additional new elements to each of them. The article will be concentrated on Science, Technology and Industrial Practice as the starting point and the most important pillar, which in close cooperation with the other two pillars can efficiently achieve the sustainable development.

MODIFIED CENTRAL PARADIGN OF MATERIALS SCIENCE AND ENGINEERING

Recycling Versus Waste

Since forever, the philosophy of any technology and industrial practice has been to produce high performance products and landfill any related process waste. Based on this philosophy the old Central Paradigm of Materials Science and Engineering was defined in 1997 by Callister Jr. [7] as:

Processing -> Structure -> Property -> Performance

The aim was to make the processing in such a way in order to get a particular structure that yields good properties which, in turn, assure good performance.

In previous publications [8, 9, 10] the author proved that this old Central Paradigm of Materials Science and Engineering is not sustainable because it it was lacking the sustainability dimension. As such, this paradigm was modified by the authors [8, 9, 10] as follows:

Processing -> Structure -> Property -> Performance **-> Reutilization/Recyclability**

The missing sustainability dimension can be explained with the fact that sustainability was not within the realm of materials science and engineering when the old paradigm was proposed, but also because Reutilization/Recyclability was considered not so important as well as difficult.

The new modified paradigm puts the Reutilization/Recyclability as an important criteria and constraint to be fulfilled for each new product starting from its first design phase and lab trials.

Linearity versus circularity

The incorporation of Reutilization/Recyclability in the Modified Paradigm of Materials Science and Engineering changes the linearity of the old Paradigm into a circular new Paradigm.

The linearity of the old paradigm is illustrated in Figure 2 where a three-link chain model shows that the deductive cause-and-effect logic of science and technology moves linearly to the right, while the inductive goal-means relations of engineering flow in the opposite direction (Olson in 2001 [11]).

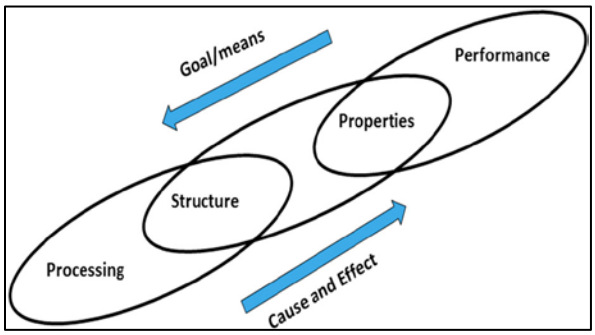

Figure 2 – The linear three link chain model [11]

By including the sustainability dimension in the form of Reutilization/Recyclability, the new Modified Paradigm is transformed by the present authors [9,10] into a closed circle as shown in Figure 3.

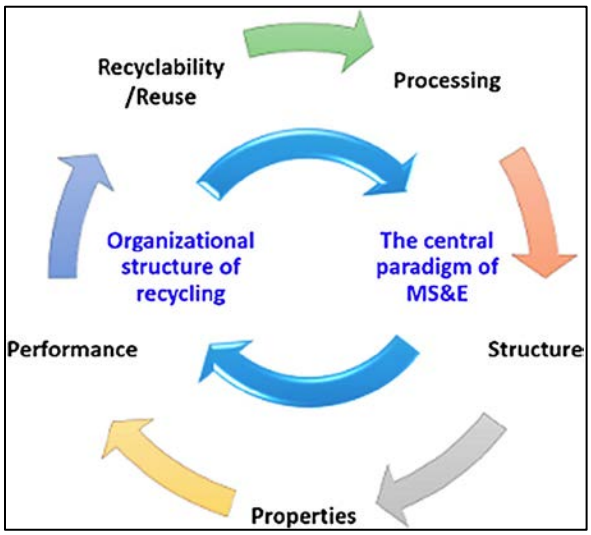

Figure 3 - New paradigm with recycling/reusing as a circular closing link [8, 9]

It is important to be underlined that Reutilization should not be understood as a mechanical activity, otherwise it will have a very limited success. It should be organically coupled with Recyclability. Recyclability means recovering of useful chemical elements from a waste or any used products through a physicochemical transforming process and reusing them chemically in the development of new products. In other terms, the chemical constituents are recycled and reused not as much as the mechanical parts.

Sustainability of the Reutilization/Recyclability

Reutilization and Recyclability are sustainable activities because they fulfill simultaneously the three criteria of sustainability. Their advantages are shown below:

In the environmental dimension:

- Protect the environment and preserves natural resources for future generations.
- Prevent emissions of many greenhouse gases and water pollutants.
- Eliminate or minimize the volume of wastes that otherwise would be increasing continuously each day.
- Save overall energy and reduce costs in the long term and in the big perspective (in the 'big picture').

In the economy dimension:

- Create and increase the add-on value if the technology used is feasible.
- Supply valuable semi-refined new raw materials to industry.
- Eliminate the need of specialized containers, specialized transportation or designated residue landfill areas and reduce the need for new incinerators.
- Promote the creation of jobs.
- Stimulate the growth of greener technologies.
- Help scientists, technologists, entrepreneurs and students save time, effort and financial resources in the overall cycle and big picture.
- Facilitate scaling from laboratory to pilot scale and subsequently to industrial scale.
- Facilitate crossing of the "valley of dead" for new technologies or shorten the time to cross it.

In the social dimension:

- Increase the living standards of the population.
- Help in profit distribution.
- Change the culture of various communities in a good direction.

However Reutilization and Recyclability have their own drawbacks [9]:

- It is much more difficult to develop a technology having reutilization and recyclability as new constraints because this necessitates new conceptual efforts. It is much easier doing without those in the rush and passion of new development.
- It is much more difficult when developing a new technology to think and plan upfront how to deal with residues. It is always easier to just throw things away, including residues, small amounts of reactants, byproducts from processes in reactors etc.
- The new technology being developed can become more complicated because not every material product is easily recycled and sometimes some of them can be easily claimed non-recyclable.

- It needs more energy in the conceptual stage, pilot plant and industrial scale in the short term or in small closed cycle/perspective.
- It requires more effort and organizational level or policy which has to be followed by everyone. That is not always the case.
- It might sometimes accidentally suppress the scientific creativity and curiosity simply because the full recycling path may not be readily fulfilled at the point when a new material is being synthesized in small quantities.
- It might sometimes negatively affect the urgency in some specific areas where superior priorities exist, such as military, energy (especially nuclear) and healthcare, where the goals to be reached can be so overwhelming that discarding materials, as opposed to recycling them, might need to be accepted to a limited extent.

It is undeniable that the advantages of recycling compared to those of not-recycling practices are far more than convincing. In a nutshell, the net gain of using reutilization and recyclability is much more pronounced in the bigger picture and in the long term perspective, compared to local and short-term disadvantages of not using it. This is compatible with the spirit of sustainability as described above.

Landfilling of waste, on the other hand, is not a sustainable activity since it does not fulfill any criteria of sustainability. As such, the landfilling of waste should be eliminated or minimized at all costs. Landfilling become a viable option only if the technology for recycling of this waste does not exist or is currently not economically feasible. The latter case makes the existing technology unsustainable because it does not fulfill the economic criteria. This is how the governing and policy actors should take the decisions in treating any waste. They have to do this in close cooperation with technology sectors and in parallel they have to create incentives to help develop new sustainable technologies for any kind of waste.

AUTOMATION

Automation has been under multiple attacks recently as an activity that wreck the middle class and takes away jobs from the society [12]. In fact, a quick look at the history of 20th century shows that automation has been perpetually under attack for similar reasons. Despite that, automation has been developing continuously and applied in all fields of life.

Taking away jobs makes automation looks like it does not fulfill the social and economic development criteria of sustainable development. However, the reality has to be looked in the big picture and not in the localized areas.

In the preface of the book Automation [13] the author describes Automation as follows:

“Automation is closely related to the modern need for sustainable development in the 21st century. One of the principles of sustainability is "Doing More with Less" which in other words, is also one of the goals of automation. By replacing the routine part of human labor with the use of machines, automation not only increases productivity and the quality of products beyond what can be

achieved by humans but also frees space, time and energy for humans to deal with the new, non-routine challenge of developing innovative and more advanced technologies. This magnificent cycle in which established developments are automated and the free resources achieved by this automation are used to develop newer technologies that are subsequently automated is one of the most successful recipes for the human race towards the goal of sustainable development."

Using the above mentioned criteria of the sustainable development, Automation is a sustainable activity because:

In the environmental dimension:

- Controls and prevents emissions of many greenhouse gases and water pollutants.
- Saves overall energy and reduces costs in short and long term.

In the economy dimension:

- Stimulates innovative growth.
- Creates and maximizes the add-on value.
- Increases productivity, efficiency and the quality of products, beyond what could be achieved by humans.
- Saves time, effort and financial resources in the overall cycle and in the big picture.
- Promotes the creation of new jobs in new sectors assuring an overall society-wide positive outcome for job creation, although in specific local sectors of routine work the jobs numbers are decreased.

In the social dimension:

- Increases the living standards of humans since by replacing routine and time-consuming duties, it frees space for more quality of life.
- Changes the human culture in a positive way by urging a continuous education for new non-routine and more innovative jobs instead of routine and time consuming jobs.
- Helps in profit distribution proportional to the innovative jobs created.

Based on the above, Automation is a genuine sustainable activity.

ROLE OF SCIENCE AND ENGINEERING

Sustainability is about resources (natural, economic and social). Until recently economic growth was the predominant criteria among those three. The economic growth was mainly achieved through industrial revolution, where the new technologies created a plethora of products having as ultimate goal only their performance. On the way, this outbalanced the other two factors: the environment was degraded and society suffered in various directions. Science and technology, while creating this magnificent growth, created at the same time problems of environmental degradation and society suffering. As such, it is logical that the solution should be first sought at the level of science and technology.

Diagnostic versus Remedial

Fortunately, as expected, is was the science itself that exposed the problems. In my previous article [14] I wrote that the role of science is credited for its scientific diagnosis of the problematic status of our planet in terms of environment and climate change, a diagnosis that was taken after numerous scientific measurements. However, the solutions seems not to be searched in the level of science and technology but generally outside it. Based on the above mentioned scientific diagnosis, numerous studies from numerous centers around the world have produced many voluminous reports about economy, social awareness, management, education and the way of life as **solutions** to the climate change issues and sustainability. Science and technology is rarely in the picture as solution provider or as a remedy factor. There is a big disproportion between the amount of public money spent in parallel in various countries on studies on economy, social awareness, management, education and way of life, compared to studies that deal with development of innovative science and engineering solutions. This is despite the fact that the studies on economy, social awareness, management, education and the way of life, although valuable, mostly repeat the same ideas and are inflationary on results and conclusions. Studies on why and how technology can solve the issues of climate change and reach sustainability are just a few and almost non-existent.

The role of science is **diagnostic** but more importantly strongly **remedial**. This has been proven times and again when the world was forecasted into trouble in 1970's because of food shortages and it was science that found the solution through new technologies that increased considerably the crop productivity.

As I wrote before [14], since climate change is caused mainly by carbon dioxide going into the atmosphere through burning of oil, coke, coal and natural gas, scientific research can develop new alternative technologies that either do not produce carbon dioxide, capture carbon dioxide and use it for beneficial purposes, or improve the risk factor of existing carbon-free technologies such as nuclear to make them acceptable to society. Science and technology make it possible to achieve all the above not only without sacrificing the current achievements of the society in the quality of life or other aspects, but also by improving and developing further the current achievements.

Science and technology, however, are not problem free:

a) Scientists have not treated sustainability as their own issue but rather as an outsider political subject. The Modified Central Paradigm of Materials Science and Engineering, as described above, corrects this.
b) New technologies sometimes miss the big picture. In their narrow field some technologies claim to be sustainable but in the big picture they are not. The management and continuous education have here a fertile ground for their contribution.
c) New technologies can be used for positive sustainable goals but also for negative non-sustainable activity. For example the dynamite invented by Alfred Nobel for mining was eventually used as an explosive in wars that followed. And here it comes one of the roles of the governance.

ROLE OF GOVERNANCE AND MANAGEMENT

Governments with their executive, legislative and juridical branches are important actors that can help achieve or undermine sustainable development. The primary role of a good government is to establish a legal framework that can help achieve sustainable development. The laws, the executive orders and the decisions of the courts need to be guided by the three criteria of sustainability: economic development, environmental protection and social development. The same criteria apply to the management of any level in the industry or any other field of life.

Related to the Reutilization/Recyclability criteria of Modified Central Paradigm of Materials Science and Engineering a good government would:

1) Financially fund the development of new economically feasible recycling technologies.
2) Set up a legal framework for efficient waste collection and helping recyclers getting the recycled materials from consumers (assuming that the recycling technologies are or become available).
3) Make aware the population for the need and the importance of sustainable technologies and good recycling practices.
4) Increase awareness of the important role that scientists and engineers play in the society and provide more incentives for students to get science and engineering university education.

Related to Automation, a good government would:

1) Financially fund the development of new automation technologies and in particular, those related to recycling in order to save human resources that are otherwise spend in routine work.
2) Set up a legal and policy frame work that offers financial assistance for continuous educations of people passing from routine manual and obsolete work to new sustainable advanced professions.
3) Make aware the population of the need for life-long education and the normality of adapting and passing from old professions to new sustainable ones.

The government actions would have limited, short term and frequently unsuccessful effects if they do not first start with the development of innovative technologies in their action scope. In case of depletion of some critical resources such as water, food or specific minerals, the government actions have very limited and short term effect if the right technologies are not available. Equally the government actions becomes much more powerful and effective when the sustainable technologies are available.

A good government does not satisfy itself by referring to scientific diagnosis about the climate change and environment degradation to justify its remedy decisions made in vacuum. Otherwise the decisions would end up against the laws of physics and be inapplicable. This has happened frequently in the last 10 years in many developed countries. A good government starts in finding solutions from science and technology and upon consulting science and engineering and counting on science and technology as the main long term solution provider.

The role of the government is also delicate. Favoring one among three criteria of sustainability can cause overall damages. Closing down all coal power plants because of CO_2 emitted in the atmosphere or all nuclear reactors because of safety issues when the alternative energies are not sufficient is not sustainable. This way the government favors in extreme the environmental protection and ignores the two other criteria of sustainability: (a) the economic development because this causes damage to the economy and (b) social development because it cases unemployment. A good government makes a balanced approach by calling science and technology to modernize coal plants, deal with CO_2 and make safer the nuclear reactors and in parallel financially funds the development of clean energies. Lord John Prescott of UK, member of the House of Lords, leader of the British Delegation in the Council of Europe in Strasbourg, member of European parliament, UK Deputy Prime Minister for 10 years in a row and member of British parliament for 40 years, recently said in one of our events: "I know some say 'close the coal industry down' and that is exactly what we did in Britain. But I do not accept that proposition. Of course there has to be a balance between renewables moving away from fossil fuels but we can't get an agreement while our total life depends on fossil fuels. The reality is that coal, nuclear and renewables will be at the central path. But we need an energy policy to achieve it, you cannot just leave it to the market to decide it" [15]

In general government potential can be used in a positive sustainable or negative non-sustainable way. In more pronounced terms, the government can force the use of the sustainable inventions of science of technology in a wrong and non-sustainable way, as it did with dynamite. That is why Lord Prescott said that the main role of the government is to design the right framework for sustainable development based on advice of science and using first technology to achieve it [15].

ROLE OF EDUCATION AND CIVIL SOCIETY

All levels of education and civil society have an important role. They need to educate people and raise awareness about:

1) The 3 criteria of sustainability and the need to fulfill simultaneously all of them.
2) The primary role of science in finding sustainable solutions for this planet.
3) The primary need to develop sustainable and efficient technologies that achieve sustainability.
4) The principles of recyclability and the need to recycle instead of throwing away or landfill whenever it exist a sustainable recycling technology.
5) The need of a lifelong education on new professions that always replace the old obsolete non-sustainable ones – a frequent phenomenon in the modern world.
6) Other cultural changes needed to achieve sustainability.

COOPERATION

Cooperation among the 3 actors/pillars is the keyword to a sustainable success. While there is enough cooperation between government and education and civil society, science and technology is left in the back burner and it is not treated as the most important actor. On the contrary, in various international meetings about the climate change and sustainable development, the technology is treated as a negative factor that makes humans badly dependent on it. This is the worst thing that can happen since only science and technology can predict and guide the society in the right direction. Without science and technology, cooperation in all other fields have very limited success or no success at all. Lord Prescott, an economist by degree, said: "Scientists tell us: you put two materials together and presumably it is predictable. When the politicians gets together around the economists and bankers …. they can use the same materials but do not guarantee you to get same results. And very often you don't. Politicians and economists then come along and say: "Oh, it is due to externalities!"[15].

Without the science and technology, other disciplines cannot predict and they need the precious cooperation of science and technology to do so. Unfortunately, many fields of education and many civil society organizations discard science and technology and have never sought its help.

As the author wrote before [14] "the winning formula to be successful and reach sustainability is a close cooperation between science, technology and engineering, politics, economy and society in equal levels and as equal partners, leaving no-one behind.

CONCLUSIONS

The confusion that exists in the definition and perception of sustainability was clarified. In one hand, the sustainable development is that development that achieves **simultaneously three criteria** (a) economic development (b) environmental protection and (3) social development. On the other hand there are **three composite actors** that can achieve or undermine sustainable development: (i) science/technology, (ii) governance & management and (iii) education and civil society. They can also be called as **pillars** of sustainability. A clear distinction between the criteria and actors should be kept always in mind and to help this a new graphical schema of sustainability framework was designed and presented. Any action in the world, life and society belong to the above actors or pillars. Sustainability **goals** are in fact the end-results to be achieved individually or in group by fulfilling simultaneously the three criteria of sustainability.

In this context, the modified central paradigm of materials science and engineering was presented along with its recyclability/reutilization dimension. Recycling versus waste, linearity versus circularity and automation versus manual work, were analyzed in terms of their advantages and disadvantages and it was concluded that recycling, circularity and automation are genuine sustainable activities that fulfil simultaneously the three sustainability criteria.

The role of science/technology, governance & management and education & civil society as the three composite actors or pillars of sustainability was analyzed and it was concluded that the

winning formula is a close and strong cooperation between them in equal levels and as equal partners.

Everyone and every profession is equally important in this world but a specific order of actions or priorities needs to be followed in order to be successful and this starts with science and technology. The technology has the first and last word. As such generous financial and human investments in in scientific research and technology is the best short and long term solution to the sustainability issues we face today.

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REFERENCES

1. World Commission on Environment and Development (1987). Our Common Future. Oxford: Oxford University Press. p. 27.
2. René Passet, L'Économique et le vivant (in French). Payot. (1979-01-01)
3. Johann Dréo, Sustainable development; March 9 2006/ Translated January 21 2007:"
4. Paul James with Liam Magee, Andy Scerri, Manfred B. Steger, Urban Sustainability in Theory and Practice: Circles of Sustainability. London: Routledge (2015).
5. Andy Scerri, Paul James "Accounting for sustainability: Combining qualitative and quantitative research in developing 'indicators' of sustainability". International Journal of Social Research Methodology. 13 (1): 41–53, (2010)
6. United Nations (2014). Prototype Global Sustainable Development Report (Online unedited ed.). New York: United Nations Department of Economic and Social Affairs, Division for Sustainable Development.
7. W. D. Callister Jr., Materials Science and Engineering, an Introduction, Fourth Edit., John Wiley and Sons, Inc., New York, USA, 1997.
8. M. Pech-Canul and Florian Kongoli; The pivotal role of Materials Science and Engineering in the Recycling of Materials, Fray International Symposium on Metals and Materials Processing in a Clean Environment, Volume 1, p. 97, Edited by Florian Kongoli, FLOGEN, Montreal, Canada, 2012, ISBN 978-0-9879917-0-6
9. M. I. Pech-Canul and Florian Kongoli; Sustainability and the Modified Central Paradigm of Materials Science and Engineering in the Development of New Materials; 2014 - Sustainable Industrial Processing Summit/Shechtman International Symposium, Summit Plenary; pp. Edited by Florian Kongoli, FLOGEN, Montreal, Canada, 2014; ISBN: 978-1-987820-11-9
10. M. I. Pech-Canul and Florian Kongoli; The modified central paradigm of materials science and engineering in the extraction and development of new and recycled materials; Mineral Processing And Extractive Metallurgy Vol. 125 , Issue 4, p. 238-241, 2016

11. G. B. Olson, Brains of steel: mind melding with materials. The International Journal of Engineering, 17, (4–5), pp.468–471, 2001.
12. David H. Autor and David Dorn, How Technology Wrecks the Middle Class, New York Times, 24 August 2013
13. Automation, edited by Florian Kongoli, Intech, Croatia, 2012
14. Florian Kongoli; Investments Needed for New Sustainable Technologies, Copper Worldwide Vol. 6 No. 1, pp. 3,8; 2016
15. Lord John Prescott; Reflections on Sustainability; 2015 - Sustainable Industrial Processing Summit; Summit Plenary; pp 7-14; Edited by Florian Kongoli, FLOGEN, Montreal, Canada, 2015. ISBN 978-1-987820-35-5