Directed and Systematic Approaches Towards Sustainability in the Twenty-first Century

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Life for me has been working on challenges, rejuvenating myself and again working for enhanced purposes. Good proposals and thoughts get non-acceptance, in the hands of a few decision-making persons, but I have learnt that a good proposal and work is accepted sometimes after a multitude of failures. Success happens when divine desires. I have gratitude for my mother, my wife, children, large family of childhood and now, school and higher education teachers, my colleagues and mentors from all walks of life in India and elsewhere in the world.

The human-dominated planet earth ecosystem, which is inclusive of all biological systems and other non-livings, is increasingly being driven by technology and social behaviours. It is, however, sustained by natural life-supporting systems and vitalized by individuals of high merit by bringing in paradigm changes amidst challenges.

The concept of ecological engineering-based engineering management is emerging as a dominant parameter to guide science, technology and innovative approaches towards green and sustainable technologies in the twenty-first century. Effective and comprehensive engineering management is intertwined with socio-economic-nature ecosystem, which is complex and multidimensional. There are systematic but sometimes hidden ecological contexts and contents. Currently, most of the technologies are oriented to mono-objective, namely open loops of material flow, and rigid products and technological processes.

Only when engineering management is placed in the perspective of an ecosystem and is focused on the concept of mutually beneficial coexistence of nature and society, an effective engineering management can be achieved and a goal of sustainable development realized. Ecological engineering can be considered as the bridge between "society economics" and nature-based cosmos. A few unique characteristics and advantages of theory and methods of ecological engineering are proposed by Xu and Li [1] for engineering management. They propose that interdiscipline of engineering and ecology leads to superiority and sustainability of technology. This is to my knowledge a robust approach for integrating engineering

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management and ecological engineering. Though the approach proposed by them is qualitative at this stage, it has the potency to evolve into an integrated and quantitative approach (based on the weightage of controlling parameters). Further useful models for desired sustainable technologies can be built. It is clearly a direction which needs to be pursued with the help of domain specialists, environment experts and social scientists.

We, human beings, inhabit the earth by occupying self-designated superior hierarchy in biological community [2]. The progress in science and technology without a balance with ecological considerations has resulted in the loss of culture, biodiversity, degradation of the earth and even the universe. This approach has also resulted in building new and hybrid ecosystems which many a times are adverse to the chain of species, evolved over millions of years. These new ecosystems can be visualized as interconnected subsystems defined by parameters such as economic growth, cultures of societies, creativity and sustainability. In this clearly highly nonlinear interconnected system, it is true that activities of human species have considered a huge disconnect with nature (eco-wealth). The basic concept of the ecosystem, for ecological research in places where people either were not in residence, or had relatively modest effect on the habitat, was that such systems were composed of organisms and the physical environment with which these interacted. Plants, animals and microbes constitute one side of the equation and air, soil, water, temperature, light, etc. the other. When these components interact, they constitute an ecosystem. Within ecosystems, man now has a predominant role to play which disturbs the delicate balance of biological system evolved so far, eventually raising a concern of getting engineered in a chaotic fashion.

It is an inescapable reality for human beings to seek “balance” and “sustainability” in the practice of technology within the ecosystem boundary, as human beings are coming to realize that the more the invasion of the nature, the more would be the environmental problems and that sometimes, these will threaten to engulf our achievements meant to improve the quality of life on this earth. The penalties for economics and more importantly for the loss of biodiversity and quality of life can be either immense or irreparable.

It is important to realize that sustainable development calls for paradigm changes in our current modes of production, consumption, decision-making and, of course, engineering management. Ecological engineering-based engineering management practices could be a beneficial attempt to make such effective changes with a systematic approach.

In the twenty-first century, “sustainable development” has become more than ever important concept in the context of economics and environmental intertwined policies. In December 1997, the Kyoto Protocol [3] aimed at addressing the global warming and the deterioration of the ecosystem. In July 2010, countries signed and ratified the Protocol. It is generally argued and accepted that the reason that “sustainability” is important is because the needs of the present are to be met without compromising the ability of the future generations to meet their needs. The sustainability should also push rather than thwart the drivers of continuously improving the quality of life of all living species on this planet.

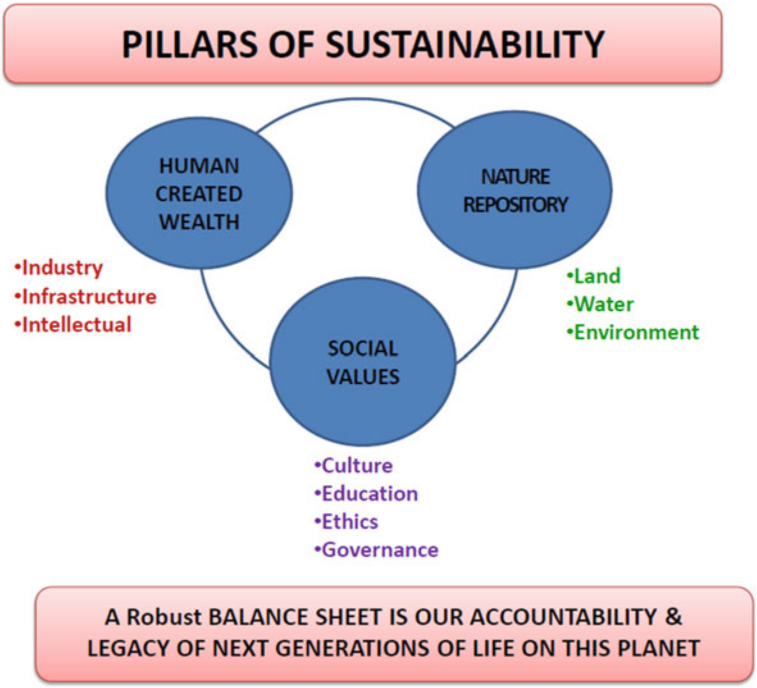

Fig. 1 Three pillars of sustainability

Sustainability in human-dominated ecosystems requires attention to three overlapping realms. An illustration of three pillars of sustainability is given in Fig. 1. The interlinkages and interdependencies are clear, but complex engineering management many a times does not take into account societal and natural wealth considerations. It also ignores cultural strengths and traditions of marginal economical groups, which are vital links in the chain of sustainability. It can be argued that such sustainable technologies are possible with proper merit-based opportunities, national policies, international commitments with clear guidance on issues such as gender equality, child labour, drug trade, low-carbon technologies, sustainable energy, water and agriculture and commitment of professionals in a cohesive and effective way towards developing sustainable technologies in an expeditious manner with clear timelines and promising measurable results.

Sustainability of technologies based on three aspects, i.e. natural wealth, human-created wealth and cultural and intellectual excellence with ethics and equity, is a robust and achievable goal. In simple words, ecological, social and economic sustainability is a challenging proposal to the current generation of professionals. Ecological sustainability is fundamental; it is about ethics and the right directions for social and economic sustainability. Social institutions, communities, culture and quality of life are integral parts of social sustainability. This is often ignored, but it is argued that this vital link needs to be incorporated in decision-making and implementation of technologies. These social features are the ways in which people organize and respond to satisfy their material and psychological needs. Economic sustainability refers specifically to the ability to derive a livelihood and to have the financial resources to participate as individuals, households and institutions in the work of the society.

These three features of sustainability, namely ecological, social and economic components in judicious combination, have to be in place for an ecological–social system to be resilient and adaptive and hence to be able to persist through interlinked changes to be brought about by relevant bureaucrats, politicians, economists and social workers. The public has to be convinced to pay the cost and bear the pains of hardships and of deriving satisfaction arising out of these changes for realizing sustainability. The countries, on their parts, should forge international treaties to realize commerce based on sustainable technologies.

Key to improving the quality of life on the earth through sustainable development is delivering synergy between the three drivers, i.e. economy, society and ecology. The term “sustainable development” recognizes that economic growth, social welfare and environmental issues are linked and must be addressed together, rather than in a fragmented way in which it is pursued and practised currently. It can be mentioned that quantum and urgency of challenge demands right actions of individuals and combined actions of right minds of organizations and countries, and at a pace which is at least an order of magnitude more than the current measure of commitments and results.

I wish to focus on my area of specialization, namely materials science and engineering. Materials are keys for technological advances in engineering management [4, 5]. Added value through materials with higher knowledge content, new functionalities and improved performances is becoming increasingly critical for industrial competitiveness and sustainable development. It can be argued that the materials themselves are the first ingredient in economic and social improvements leading to progress.

Sustainability based on engineering management leads to new demands for materials. Sustainable materials and sustainable materials management (SMM) are needed for sustainable production. The OECD working definition of SMM was developed in 2005, and it states: “Sustainable Materials Management is an approach to promote sustainable use of materials, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials, taking into account economic efficiency and social equity”. Materials technology impacts a manufactured product by its choice of materials (metals, ceramics, glass, polymers, etc.) and processing steps (shaping, joining, finishing), recycling, etc.

I illustrate my perspective with a few examples taken from the literature and private communications [6]. Aluminium is a green metal and a good replacement for wood. Aluminium helps in protecting forest covers. Aluminium industry is continuously facing opposition from environmental ministries and non-governmental organizations. The discovery of East Coast bauxite deposits in the late 1970s has put India on the world aluminium map as the fourth country with more than 3 billion metric tonnes of bauxite reserves. Mineral resources are non-renewable. However, their life can be stretched through adoption of new technologies at various stages of production, processing and use. Moreover, aluminium industry is sensitive from environmental angle, and hence, careful planning is a must to ensure that impact on the environment due to mining, refining and smelting operation is the least.

Researchers in India are pursuing a road map with innovative technologies for alumina and aluminium industry, such as zero waste refinery, water management and red mud management. Prioritized development of science and technologies is enabling India and the world to adopt cleaner and greener technologies. K.K. Khanna [7] recommended a new environmentalism to have acceptable intertwining of technology and management, and the involvement of environmental specialists from the inception of improvement in technologies to have better results of acceptance and competitiveness. This approach is different to that of Xu and Li, mentioned earlier in the article. The two approaches need to be practised in a few case studies to achieve maturity based on validated successes.

India has done well in engineering management towards sustainable green environment-friendly technology in leather processing. There is a need for transition from a “Don’t-ecology” to “Do-ecology” approach in leather processing. It has been recognized that end of pipe treatments in isolation is not an adequate strategy to meet the requirements of wastewater norms and standards. J.R. Rao communicated with me to state that an ideal approach is to target the zero or near-zero discharge of waste liquors by appropriately modifying the leather processing. To reach the desired targets, engineering management based on ecological sensitivity has been researched and developed.

Further resources are focused on newer green science and integration with ecological consideration to environmental technology and cleaner technology [8]. Desired approaches, such as “reverse leather processing”, “natural colours” and “chrome management”, are pathways to realize the goals. Research at Central Leather Research Institute, Chennai, has proved that the innovative approaches enable a significant reduction in chemicals, time, power and cost. Thus, green and ecological engineering is possible and can be made competitive in even small industries with little expertise in advanced science and technology which would be a basis for realizing sustainability and economic growth in a cohesive and inclusive manner.

I would like to dwell in brief on energy security and sustainability, another area on which I have been engaged for almost four decades [9–13]. Adequate availability of energy to all the citizens, high GDP growth along with the concerns and threats of climate change and sustainability doctrines are the corner stones of the energy policy of India. The policy focuses on judicious choice and a mix of fossil, hydro, nuclear and renewables. The policy also balances progress and GDP growth for removing poverty, vis-a-vis climate change concerns, economics of energy and energy security.

Environmental concerns are associated with all forms of energy including fossil fuels, nuclear energy and renewables, throughout the energy chain from exploration, mining, transportation and generation to end-use. Life cycle considerations

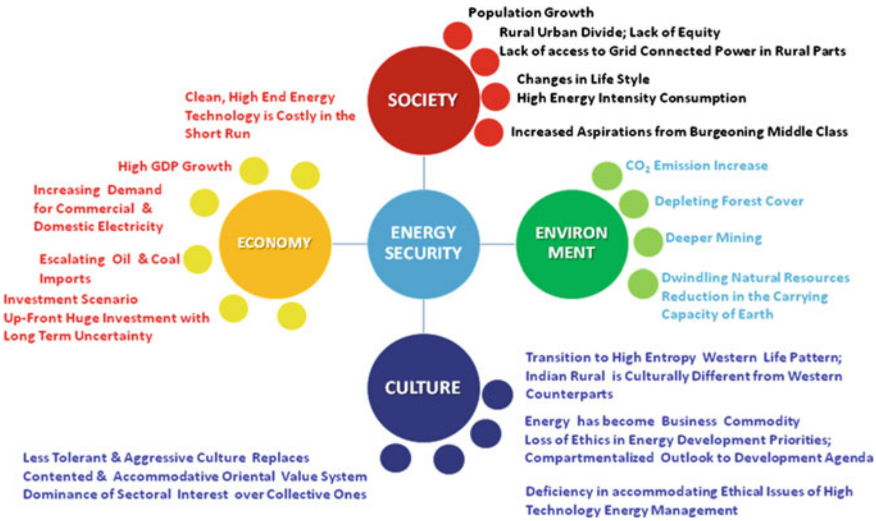

Fig. 2 Energy security: a multidimensional challenge

and risk management in new technologies combined with technology foresights are key to success in the energy demand facing India. Energy security is a multidimensional challenge (Fig. 2). It can be argued that without meeting the challenges of energy security with sustainability and affordability, Indian dream of being one among the first five countries in the world will not be realized. I am of the view that current models for forecasting energy needs assumptions in balance of energy resources and technologies, forecasts and foresights of individual technologies, essential availability of human resources, dynamism in sustained policies, etc. need engagement of appropriate experts drawn from fossil, nuclear, renewable, hydro, social sciences, climate change, specialized bureaucrats and politicians. We need an empowered mechanism for India to meet the challenge for the vital need of India, i.e. ensuring energy security, affordability and sustainability. India, by achieving success in this challenge, can be a pioneer nation for other nations to emulate and can simultaneously grow huge business (internal and external) for our growing economy. The challenge also provides a fertile area for national and international collaborations in science and technology at the cutting-edge frontier. Moreover, achieving this challenge in a cohesive manner shall enable establishing a robust mechanism for meeting other challenges, say in water, health care, infrastructure, etc. Currently, our R&D intensity, concepts to maturity pipelines and strategies are immensely inadequate in comparison with the challenge.

I wish to utilize this opportunity to dwell specifically on roles and concerns about nuclear power for energy security. The assessment of the risks of nuclear power generation should be done in the context of climate change and change the use and production of energy towards meeting large unsatisfied needs of the country now and in the coming decades, of our growing economy and the citizens of India for better quality of life. From the analysis, it can be argued that nuclear energy has to be utilized much more intensely in the decades ahead in the Indian context. India has done well to make significant advances in science and technology of water reactors, sodium-cooled fast reactors, thorium technologies, etc. for energy and in developing mature expertise in interrelated comprehensive range of science and technologies spanning almost all domains of science (including mathematics and life sciences) and technologies such as food, health care and water. India is among the world leaders in fast reactor programme with closed fuel cycle, a sustainable energy source, as assessed by International Atomic Energy Agency and leading countries of the world (Gen IV). This energy system is sustainable over centuries and can be made competitive in cost, once developed, with relevant science and technology, and operated in a business model based on a large-scale exploitation of this system. India is also a clear leader and pioneer in thorium technologies.

The concern for nuclear energy is the probability of access of fissile materials (by wrong hands) safety under extreme conditions of accidents and management of high-level wastes. Indian nuclear programme, encompassing three stages and doctrine of closed fuel cycles, has a clear possibility of addressing these concerns with significant improvements. The current challenges include scaling the quantum of nuclear energy to be multiplied expeditiously and public acceptance on the merit of informed opinion and not myths. The country and the Department of Atomic Energy need to initiate a well-conceived paradigm changes in the strategy to meet these vital future challenges to enable nuclear power to meet the energy demands when it is needed most that is now, in the next decade and a decade later.

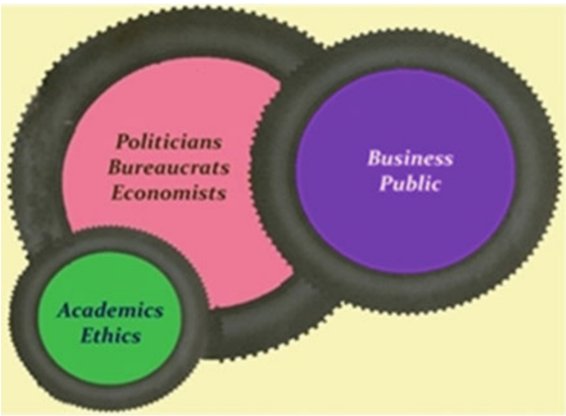

Fig. 3 This scheme shows overindulgence of business, politics, bureaucracy and economics combined with out-of-proportion interventions by the public. The steering wheel is essential in the hands of academicians and outstanding professionals in all domains with the clear mandate for balancing growth, equity and sustainability

In the twenty-first century, it is an inescapable context and trend for humans to seek a balanced mix of nature wealth—economy and societal drivers for attaining "sustainability" in the practice of materials, technologies and energy while continuing to improve the quality of life on this planet with higher ethics and equity. Currently, a disturbing feature amidst population of 7 billion human beings is vivid signatures of fatigue and even failures which need to be corrected with clear results to generate confidence and pave clear pathways towards sustainability. These requirements demand new approaches, innovations, materials and technologies. I have depicted in Fig. 3 that academicians and intellectuals in all domains should take the steering wheel to guide the society for balancing the progress with ethics and sustainability.

References

1. Xu JP, Li ZM. A review on ecological engineering based engineering management. Omega. 2012;40:368–78.
2. Ma SJ, Wang RS. Social-economic-natural complex ecosystem. Acta Ecol Sinica. 1984;4 (1):1–9.
3. Kyoto Protocol: Status of Ratification. United Nations Framework Convention on Members of the Commission. Our Common Future. In: World Commission on Environment and Development (WCED). Oxford: Oxford University Press; 1987.
4. Fiksel J. A framework for sustainable materials management. JOM. 2006;58(8):15–22.
5. Jacobs JA, Kilduff TF. Engineering materials technology: structures, processing, properties, and selection. 2004; 67:2.
6. Kumar M. Future prospects and challenges in aluminium industry in India. Metal News. 2011;14(4):14–9.
7. Khanna KK. Environment policy—a global perspective. IIM Metal News. 2011;14(5): 9–13.
8. Rao JR. Cleaner technology paradigm: a case of leather making. Central Leather ResearchInstitute, India (Personal communication).
9. Raj B, Rajan M. India's fast reactor programme in the context of environment sustainability. Int J Environ Stud. 2007;64(6):729–47.
10. Chichilnisky G. What is sustainable development? Land Econ. 1997;73(4):467–91.
11. Raj B, Raju S. Materials for energy systems. Kolkata: Publication of Indian Institute of Metals; 2013.
12. Raj B. NP Gandhi memorial lecture, energy, ethics and equity. IIM Metal News. 2011;14 (6):15–25.
13. Walter AE, Todd DR, Pavel V, Vetkone TS. editors. Fast spectrum reactors. In: Raj B, editors. Core materials. Berlin: Springer; 2012.

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