Entropy Management Along With Energy Management for Sustainability

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Abstract— Climate change and Energy security issues are addressed mainly by interrelationship between Energy, Ecology and Economy, affecting Employment and Equity. But increasing economic growth of nations has only increased gap between rich and poor. Two more parameters, Entropy and Ethics play important role. The paper brings forth role of these parameters, using fundamentals of Thermodynamics and explores better solutions for handling such issues.

Humans convert energy from difficult-to-use to easy-to-use forms, like chemical energy of wood to heat, energy of fossil fuels to electricity, etc. Throughout history, man has developed ways to expand his ability to harvest energy. Modern Technological Man of 1970 consumed about 115 times more energy per day than that consumed by primitive man. Industrialization/Technology Age consists of appearances/usage of new energy sources, fossil fuels, having higher energy concentration. Changed life-style/economy in new industrial society make success a function of quantities and types of energy resources exploited and conversion efficiency of potential energy to work and heat. Increasing energy consumption closely matches modernization. In Large Scale Economies, centralized production in heavy industries, backbone of Modern Global Economy, causes large scale emission of pollutants, beyond recuperative capacity of atmosphere, causing loss to Ecosystem. Increasing Energy Efficiency at micro level reduces energy consumption of artifacts, but at macro level, due to materialistic world view, social consequences needing attention arise, e.g. increased fuel-economy of cars, boosting their sales, with a net rise in fuel-consumption in India.

The Second Law of Thermodynamics, defining Entropy, in extended form demands rethinking on concept of 'progress' as we have finite endowment of energy/material resources. As systems get organized, their entropy decreases at the cost of entropy of systems (including humans) contributing to organization. Considering Biosphere as open thermodynamic system, exchanging matter, energy and entropy with its environment, rest of Universe, to get more organized, Biosphere requires influx of Negative Entropy from external sources, mainly Sun to conform to Second Law. Global warming causes temperature rise of Earth and Biosphere, hence decrease in availability of Negative Entropy from Sun and increase in loss of Negative Entropy from Earth and Biosphere to universe – there is loss of available Life-Force, evident as increased chaos. So, along with energy, there is another important (related) natural resource, Negative Entropy. We need to understand Entropy balance and how human activities affect it at micro/macro levels. The author suggests Entropy management (by Entropy Ratings of systems/processes) along with Energy management.

Keywords : Second Law of Thermodynamics, Entropy, Negative Entropy, Entropy Management, Entropy Balancing, N-entropy, Entropy Ratings, Sustainabiltiy.

1 INTRODUCTION

ENERGY – ability to do work – a scalar physical quantity that describes amount of work that can be performed by a force, is an attribute of objects and systems that is subject to the Law of Conservation of Energy. Without energy, life cannot exist. Anything that happens in the universe is a manifestation of conversion of energy from one form to another. Historically, any change in the prime energy source of a society has resulted in a revolution in the life style [1], as shown in fig. 1.

Energy utilization affects modernization [1], as shown in fig. 2. As the sizes of economies of all nations increase so do the industrial activity, consumption of fossil fuels and consequent global-warming. This adversely affects the economy.

Figure 3 shows the influence diagram of energy-ecology-economy inter-relationships and their consequences. A + sign at the head of an arrow indicates that a change in the variable at its tail influences the variable at the head of the arrow in the same direction and vice versa.

Most Renewable Energy Sources like solar energy and bio-fuels are diffused energy sources and thus are more suited for decentralized production systems.

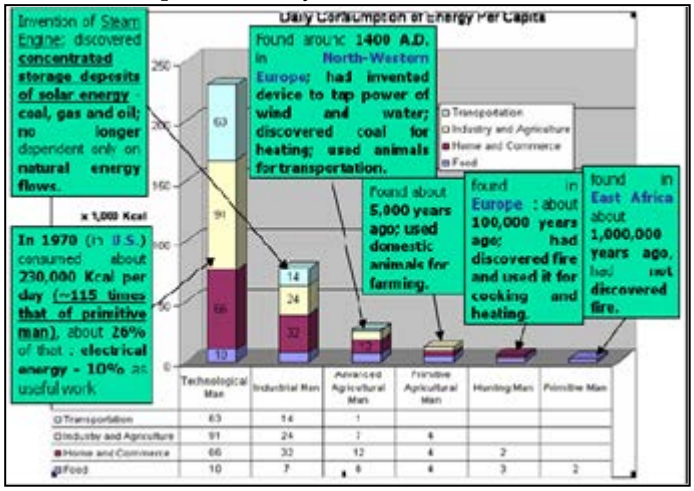

Fig. 1 : Estimated Daily Consumption of Energy per Capita at Different Historical Points [4]

Ideally the projected increase in the share of renewable energy in future should to be accompanied by changes in the production systems. This linkage is often not appreciated resulting in enormous waste of energy. It is important to disaggregate the factors 'Economy' and 'Energy' in an omnibus manner. Thus, increasing use of renewable energy, which is diffused by its very nature, would not only improve ecology, but also promote employment and equity in the society, which are greatest need of the modern times.

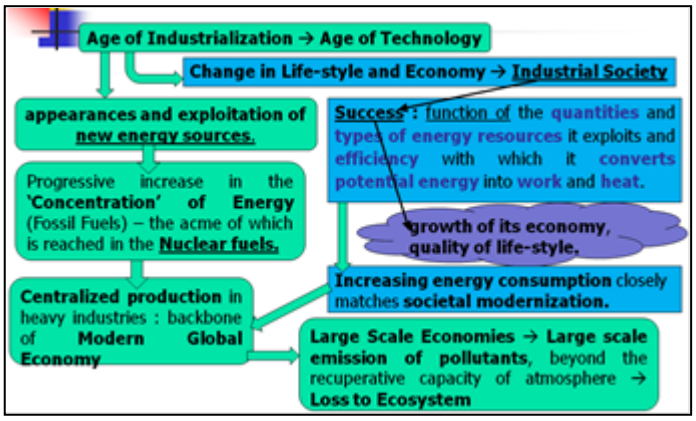

Fig. 2 : Effects of Energy Utilization on life style and economy.

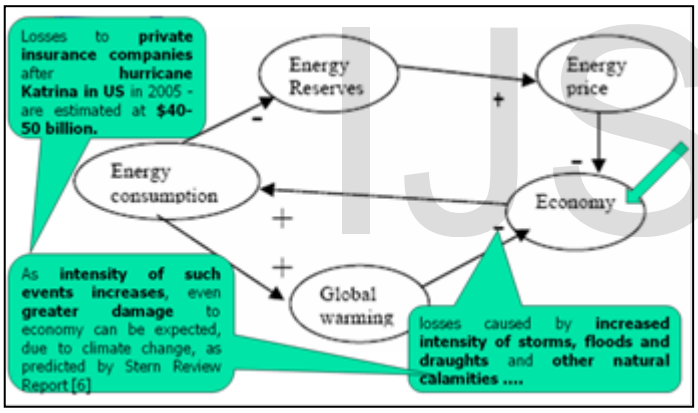

Fig. 3 : Energy-ecology-economy Influence Diagram [1]

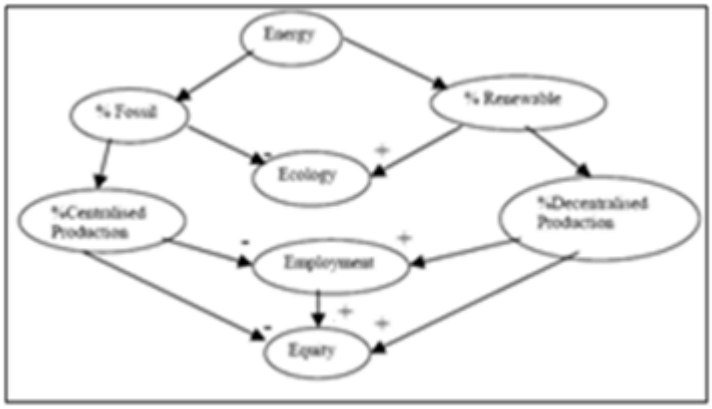

Fig. 4 : Energy-ecology-economy-employment-equity Influence Diagram. [1]

By using the concept of Appropriate Technology, the right choice of technology can be made. Appropriate Technology is a concept, a set of ideas or a framework aiming at providing a basis and a method for choice of technology. In the sphere of technology, the concept questions the indiscriminate use of mass-producing western sophisticated technology and puts new constrains for local need and use. On the philosophical plane, it relates to the concepts of peace, non-violence and permanence and stresses dignity and the ethics of work. Within the context of planning, the concept puts emphasis on both short and long term policies that will encourage self-reliance, on bringing points of production and consumption (both in space and time) closer, and on decentralization with respect to planning and decision-making within the regional approach [7].

2 Entropy And Ethics

Most attempts to address climate change and energy security issues have been based on interrelationship between three of the Es mentioned above, viz. Energy and Ecology and Economy. The focus is generally on improving the energy supply, distribution, and usage efficiency through better power plants, newer renewable sources of energy, fuel efficient vehicles, efficient lighting systems, efficient air conditioning systems, improving the agricultural crop yields, Reducing emissions by shifting to non -carbon energy (like nuclear energy, which unfortunately is too hazardous ….), capturing carbon dioxide, etc. thus trying to reduce poverty by increasing economic growth. These suggestions seem quite logical prima facie, but, increasing economic growth of nations has only increased the gap between the rich and the poor, as can be seen from fig. 5.

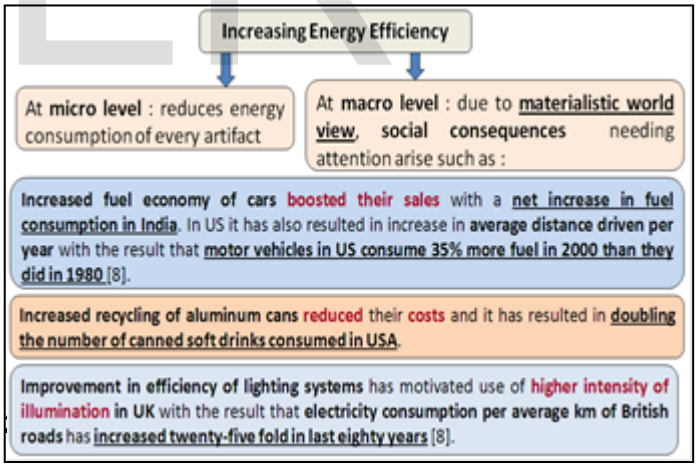

Fig. 5 : Drawbacks of merely increasing energy efficiency.

Clearly there is a need to account for the influence of the societal world view on the pentad of energy, ecology, economy, employment, equity. It is proposed to do so by introduction of two more Es, namely Entropy and Ethics.

In many branches of science, Entropy is a measure of the disorder of a system. The concept of entropy is particularly notable as it is applied across Physics, Information Theory and Mathematics [9]. It is a measure of the disorder of molecules in a system, which uses the concepts of reversibility and absolute temperature, and is central to Second law of Thermodynamics and to Fundamental Thermodynamic Relations, both of which

deal with Physical Processes and whether they occur unexpectedly. It is an Imaginary extensive property, from Greek word for transformation by Clausius – as a measure of "Transformation Content" of a body, given by, s = (dQ/T) kJ/K, i.e. the ratio of heat change to absolute temperature at which the change takes place.

Entropy is also considered as a measure of the "multiplicity" associated with the state of the objects. If a given state can be accomplished in many more ways, then it is more probable than one which can be accomplished in only a few ways. This means that if a given ordered state can be accomplished in many more ways than a disordered state, multiplicity will favor this state. Thus, entropy can choose order as well as disorder. Thus, systems should be maintained at most ordered or lowest possible entropy state. Spontaneous changes in isolated systems occur with increase in entropy, which tend to average out differences in temperature, pressure, density, and chemical potential, so, entropy is a measure of how great unexpected changes are [10].

Although the concept of entropy was originally a thermodynamic construct, it has been adapted in other fields of study, including Production Engineering and Preventive Maintenance, Mathematics and Information theory, Psychodynamics and Neurology as Psychological Entropy and Spectral Entropy, Sociology and Thermoeconomics as Economic Entropy, Social Entropy and Corporate Entropy and Evolution. As per the second law of thermodynamics, extended to economic systems [11], 'entropy' is used in a generic sense to indicate need to look at energy issues from a broader perspective. 'Extended' second law states that all natural processes involve exergy and material dissipation, exergy being the thermodynamic term for the maximum useful work that can be obtained from any energy source. Rate of dissipation of exergy/matter largely depends upon exergetic efficiency of the artifacts (related to entropy) used and lifestyle of the people (related to culture, values and ethics). This law thus demands a rethink on the whole concept of 'progress' since we live in a planet with a finite endowment of energy and material resources [12]. The second law thus makes it clear that no amount of technological innovation can sustain limitless growth in a planet with a finite stock of minerals, metals, fossil fuels and finite flow of solar energy. It is thus imperative that a shift be made to sustainable levels of consumption. This can be understood from the following discussion : In his work titled "Life on Earth – Flow of Energy and Entropy", Marek Roland-Mieszkowski [4] puts forward the idea of Negative Entropy driven systems. He explains the concept of Negative Entropy – first introduced by E. Schrodinger [5] or Information [13] and the ability of the Biosphere to effectively extract it from the Sun's radiation, which is very important for life on Earth. He says, entropy of one system can be manipulated via another system, such as, during production of clothing, cars, chemical compounds etc., entropy of the system decreases as the components are organized. However this is done at the expense of the manufacturing system (including people) whose entropy will increase during this process. In a refrigerator, entropy of air is decreased by lowering the temperature, at the expense of increased entropy of the environment and the refrigerator. Biosphere – all the matter which is used to 'build' living organisms, part of this matter in the living organisms and part in the 'recycling' stage – is considered as an open thermodynamic system, which can exchange matter, energy and entropy with the environment – defined as rest of the Universe, including radiation. To get more organized, the Biosphere requires an influx of 'negative entropy' from external sources. The main sources of negative entropy are Solar Energy and Geothermal Energy (does not contribute significantly). The Sun's energy is highly organized and carried by photons. Biosphere absorbs this energy and then releases it back to the Universe as the global energy balance is zero. Energy released to the environment is in the form of electromagnetic radiation, which is on average at longer wavelengths than the absorbed photons. The black body radiation of the Sun (5800 K), which is absorbed by the Biosphere has a much higher temperature than the black body radiation from the Biosphere and Earth (280 K) flowing to the Universe (3 K), as shown in fig. 6 and 7.

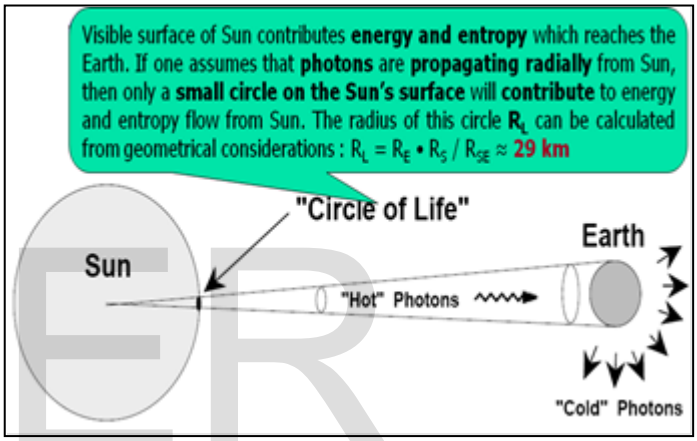

Fig. 6 : The Biosphere absorbs "Hot" Photons from the Sun and emits "Cold" Photons at longer wavelengths. Energy and entropy flow from the Sun is equivalent to the total energy and entropy flow from "Circle of Life".

Fig. 7 shows Three Thermodynamic Subsystems – Sun, Biosphere and Universe. The Biosphere extracts negative entropy in the process of exchanging "Hot" Photons (Black Body radiation at T= 5800 K) to "Cold" Photons (Black Body radiation at T=280 K). This process is responsible for the mysterious "Life Force" which seems to defy II Law of Thermodynamics. On the basis of this theory quantitative calculations of total "negative entropy" balance on Earth, can be made.

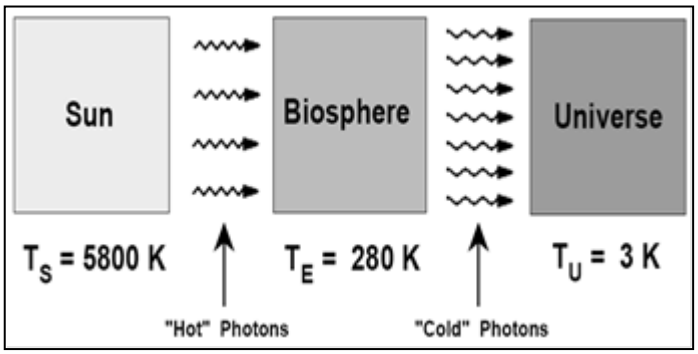

Fig. 7 : Thermodynamics of Life.

Thus, the Biosphere does not accumulate energy when it is in steady-state condition, but it accumulates negative entro-

py and increases in organization. This is the difference between the entropy of absorbed radiation and emitted radiation – at longer wavelengths of photons. Only about 0.5 m² of the Sun's surface is available to supply the needed energy and negative entropy for each person on Earth. It is estimated, that currently only about 1% of Sun's radiation is absorbed by the photosynthesizing organisms [14].

Figure 8 shows the entropy flow in creation and maintenance of systems.

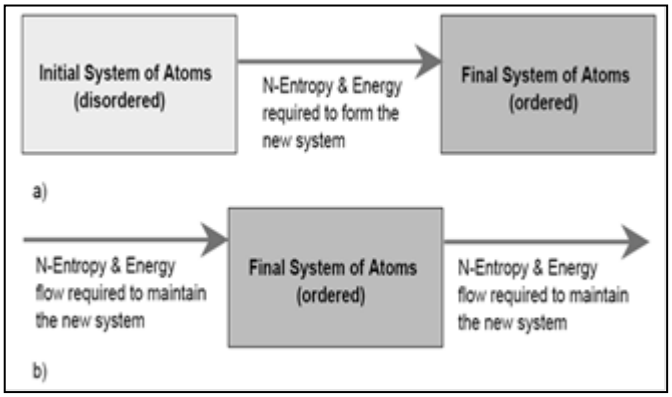

Fig. 8 : Creation and maintenance of system – flow of entropy – a) In order to form Final System certain minimum N-Entropy (Information) and Energy is required. The particular N-Entropy and Energy used will depend on the efficiency of the process. b) In order to maintain Final System certain minimum flow of N-Entropy (Information) and Energy is required. The particular N-Entropy and Energy flux will depend on the efficiency of the process.

Interdependence of the organisms in the Biosphere can be illustrated by "Pyramid of Life". Base of this pyramid is occupied by organisms which are utilizing photosynthesis for extraction of energy and negative entropy from the Sun's radiation. Other organisms are utilizing energy and negative entropy stored in food, during the process of digestion.

Figure 9 shows the Pyramid of Life, along with some important observations on it.

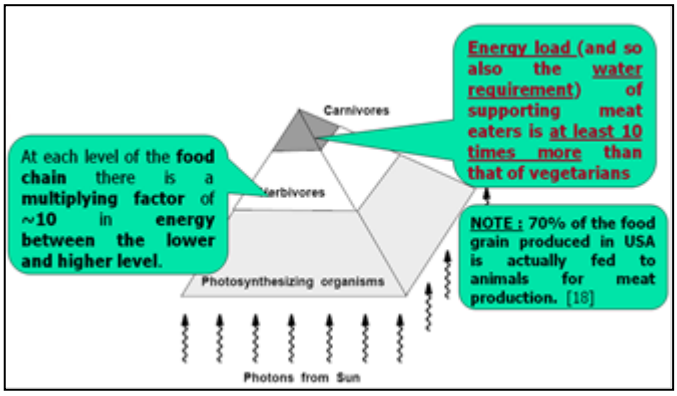

Fig. 9 : Pyramid of Life.

The influx of the Sun's energy and negative entropy will not be able to sustain our growing population and growing individual consumer demand. A closer look at the above numbers raises the question : Do we want to survive ? Do we want a decent life ? Limiting the Earth's population and lowering individual consumption of energy and negative entropy is essential for the survival of the Biosphere.

Global warming is causing increase in temperature of Earth and Biosphere, so the decrease in availability of Negative Entropy from the Sun and the loss of Negative Entropy from the Earth and Biosphere to the universe – both are on a rise. This means, there is loss of available Life Force – which shows in the form of increased chaos.

Thus, along with energy, there is an important (related) natural resource – Negative Entropy, which needs to be taken care of. There is need to understand the process of Entropy balance and how human activities affect it at micro as well as macro levels. There has to be Entropy management along with Energy management.

Figure 10 shows effects due to entropy changes. Measurement of entropy changes of a system can be done by methods illustrated in fig. 11.

Entropy ratings can be recommended for processes / activities as well, in ergonomics – for people who work under trying working conditions.

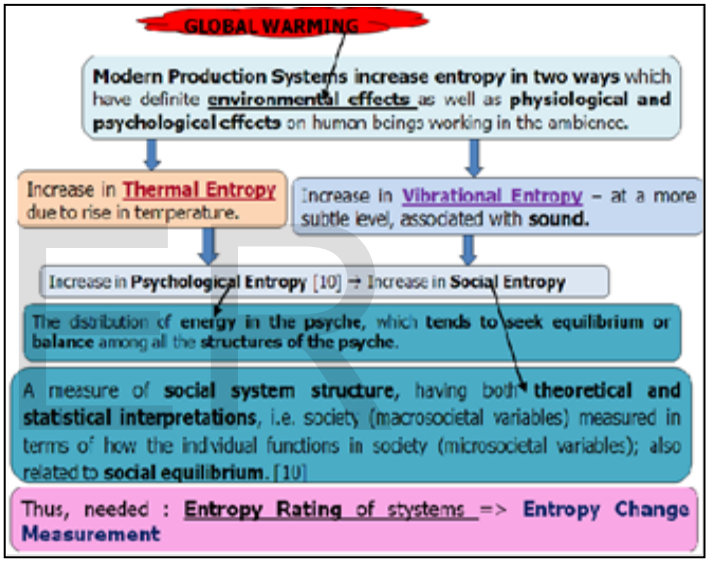

Fig. 10 : Causes and effects of entropy changes at various levels

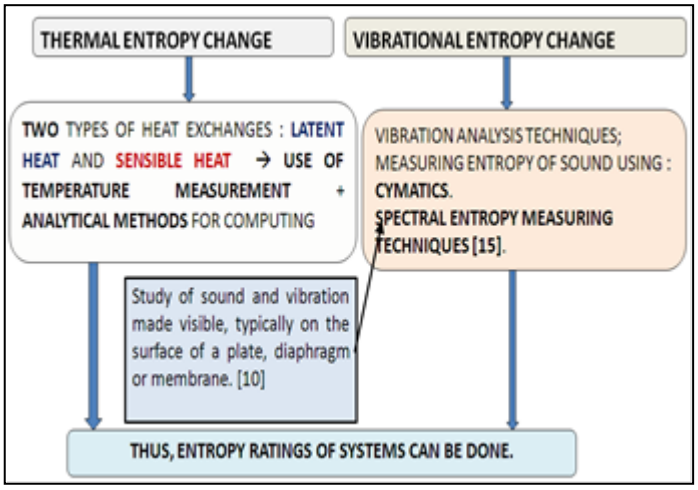

Fig. 11 : Measuring entropy changes.

3 Sustainable Development Through Entropy Management and Ethical Life-style

Even the mainstream economists now recognize quality of life as a multidimensional concept involving satisfaction of a variety of needs which can be broadly classified into physical, emotional, intellectual and spiritual needs, as put forward by Abraham Maslow [17]. All these needs are important, and are not substitutable. But while the needs are finite – how much food one can eat, how many clothes one can wear or rooms one can live in – wants can be infinite. Driven by materialism, if one does not exercise self control and / or lacks a proper understanding of human happiness, these 'wants' become 'needs'; one stagnates at the level of satisfying these unending 'physical needs', and gets no opportunity to satisfy the higher needs. This lack of satisfaction of emotional and other higher needs leads to perpetual discontentment and one tries to alleviate that discontentment with physical goods, power and authority. This results into unbridled consumerism and egotistic behaviour, which are at the root of energy-ecology crisis. It is a cumulative phenomenon. The idea of cut throat competition found in the Darwinian concept of "Struggle for existence" and "Survival of the fittest creeps in under such situations. In a symposium on "Beyond Conflict : Transcending Us and Them" held in Washington in 1889, Robert Augnos and George Staincill had said, "Nature knows that fighting is foolish, it wastes time, it wastes energy, it risks unnecessary injury and it makes no sense …. Fish provide another example. There are a total of 21000 species in the world. Each fish has its own food, its own lifestyle, and makes its own living in a way that does not compete with others, even if they are living in the same area …. This pattern of non-competition is typical of all naturally co-existing species. Peaceful co-existence , not struggle, is the rule." According to the great ecologist Konard Lorenz, "Animal with the most dangerous weapons also are equipped with strongest instincts not to use weapons on their own kind. The only exception to this rule would be Man." [21]

A century ago, Swami Vivekananda had foreseen this problem of materialism and said, "Materialism and all its miseries can never be conquered by materialism …." His vision was that of a nation / a world, a system which had a combination of western efficiency and dynamism with Indian spiritual values.

As per a survey (London School of Economics) a few years ago, happiest country in the world is Bangladesh (very low per capita income), India is 5th and many developed countries are far behind. So, happiness is proportional to money is a wrong notion [18].

There is a story in Panchatantra, of two friends, a florist and a fisherwoman. One day, the florist takes her fisherwoman friend home, excited at her long-awaited invitation being honoured. The fisher-woman puts her basket of fishes near the doorstep of her friend's house and spends her day, amidst the deluge of outpouring hospitality of her loving friend. At night, however, sleep eludes her. Concerned, the florist inquires about the reason of her discomfort. The fisherwoman reveals that the fragrance of flowers in the house was irritating her. She brings her fish basket from outside, sprinkles water in it, places it on her bed-side and falls asleep. The story brings forth the importance of habits, which we knowingly or unknowingly cultivate. We are used to a life-style which has led us to the present crisis. An important aspect of the solution to it is an education system which will help us develop knowledge, technology and attitude for sustainable living, as shown in the influence diagram in fig. 12.

Such an education would enable us in changing life style, rather going back to old life style, like elimination of use of : bottled water, frozen foods (we live in an era of junk food, junk music ….), electric geysers (Solar water heating systems are better options), paper towels (Loss to ecosystem in terms of energy and negative entropy should be computed to find out the tremendous ill-effects), international trade in fruit and vegetables (many countries import and export millions of tons of the same commodity, see reference [19]) , remote controlled electronic gadgets (which continuously leak electric energy even when not operational) etc. Also it would encourage eco-friendly technology and life-style which include activities that decrease entropy, like planting trees / gardening / farming with zero-fossil fuel input, Meditation, listening to the right kind of music, creative pursuits, developing and implementing right perspective towards life, etc.

The 1962 UNESCO Report on Education, titled "Education to do" described the goal of today's education as an attempt to make a 'complete man' – the evolution of "Homo Sapiens" to "Homo Mysticus" and says, "The physical, the intellectual, emotional and ethical integration of the individual into a complete man is a broad definition of the fundamental aim of education." [20]. Education system in sustainable and ethical living will realize this concept.

Entropy management and ethical life-style, thus provide an answer to the problems in the form of a framework from which can emerge holistic response to energy-ecology crisis.

Fig. 12 : Education for sustainable living.

4 CONCLUSIONS

Taking a holistic approach for solving the present ecological crisis can enable us find an appropriate solution. This involves taking the two important factors, entropy and ethics into consideration, which have not been given due importance while choosing technology and which has resulted into the greatest crisis of the modern times.

Large centralized mass production systems, dependent on burning of fossil fuels, have caused increase in entropy beyond the recuperative capacity of the environment. Entropy studies, leading to entropy ratings of systems / processes / activities should be adopted to control and prevent the harms caused by such systems / processes / activities. The harmful effects of global warming get cumulated by the loss of negative entropy which it brings along.

Also, simply ensuring increase in energy efficiency aggravates problems due to ignorant materialistic attitudes. So, ethical lifestyle should be adopted. Education can play a vital role in bringing about and spreading the knowledge, technology and appropriate attitude required for sustainable growth and existence.

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