Abstract: Industrial symbiosis and the qualitative optimisation of chemical fabrication methods are described as the means to attaining eco-friendly technologies. However, it is argued that the sustainability of any organised pattern of human interference with the supporting natural substrates could not be predicted with the absolute accuracy. The overwhelming complexity of ecological relationships prevents a perfect deduction of the complete spectra of effects that human pathways of production and/or consumption bring forth. As a solution, the restoration of approaches that take into sustainability accounts the deepest aspirations lying at the foundations of human strivings towards the improvement of life qualities is suggested. The major thesis of this work is, thereupon, in sympathy with the idea that the key to achieving truly sustainable networks of human creativity may lie not only in apparent causes initiated by human deeds, but also in the benevolence and grace of impalpable and ineffable sprouts of our actions in the world.

Keywords: chemistry; complexity; diversity; ecology; ecosystems; ethics; industrial symbiosis; sustainability; uncertainty; zero-waste.


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1 Introduction: various paths to sustainability

“And so we see that every community may be divided into four parts: first, its members with their immediate environment; second, the distant and unknown lands that send out their influence by stream and wind, by wing and padded foot to affect the local environment; third, the actions of men whose influence spreads out to affect in some way nearly every community living on the earth; and last, but most important, those influences that mold the minds of men,
giving them the incentives to wise or unwise action; for in the end these lie at
the very center of earth’s great web of life” John H. Storer, The Web of Life: A
First Book of Ecology.

The major conclusion that can be elicited from the current global concerns over the
problem of sustainability is that the development and the implementation of any novel
technology become useless unless its sustainable interaction with the corresponding
environment is provided. In accordance with this starting point, efforts should be paid to
ensure incorporation of the attributes of sustainability within each segment of the
anthropomorphic planetary organisation.

Sustainability has been defined as ‘a basis for creativity which does not degrade the
living conditions of the forthcoming generations’ (United Nations, 2002; Thomas and
Assadourian, 2003). Such a definition may invoke many wise imperatives from the old
traditions of our civilisation, including the famous guiding principle of Indian chiefs,
according to which

“when any act of creation is conceived, the consequences which our deeds will
leave to the seventh generation from that moment on should necessarily be
considered”.

However, despite the fact that it can be easily defined (Pope, Annandale and Morrison-
Saunders, 2004), sustainability does not present only an exceedingly intricate term in
practical contexts, but is, as we shall see, insurmountably elusive to measurements and
assessments.

Highly developed ideals are nowadays, more than in any other time in the human
history, meeting and confronting in numerous areas of the global society. When the
question of sustainability is raised, two major currents appear. One belongs to the belief
that only returns to more widely interspersed agricultural lifestyles that leave the
promises of the industrialised society behind would revert the human society to
sustainable frames. The other one belongs to the predominant optimistic beliefs of the
modern science that novel technological solutions will fix the problems that the scientific
progress itself has left in its wake. An implicit idea of the latter standpoint is that the
sustainable settlement of the global society may be attained by subjecting naturally
developing ecological diversities to even more of the artificial control. The aim of this
work is to present the parallel pursuit of these two paths as the most convenient option for
the development. This is in concert with the ideal of ‘middle ways’ as solutions that
approve the relevancy of all the proposed options, and thereupon educe harmonious
directions of progress.

The basic assumption underlying the ideas proposed in this paper is, accordingly, a
simultaneous human autonomy in relation to the environment and their intrinsic
dependence thereon. On one hand, the human civilisation can persist only in the same
extent as the supporting ecological diversity is preserved. On the other hand, as the most
intelligent and creative planetary creatures, humans are apparently capable to modify the
order of their environment. From the current standpoint in time, sustainability of our
civilisation will crucially depend on both. For, only an active stewardship of the
environment coupled with a controlled direction of natural processes can bring about the
prospects of sustainable evolution to the face of the Earth.
2 Symbiotic industrial arrangement as a means to sustainable future

Permanent waste is non-existent in the natural world. For, every by-product in the biological domain becomes absorbed as food or the source of action by complementary species in the corresponding food-chains or ecological networks of relationships. However, the traditional industrial production has followed the trend of yielding the desired objects whilst leaving aside by-products, frequently consisting of permanent, non-biodegradable wastes. Taking into account that the scientific and technological progress has on many occasions throughout the history of human civilisation initiated an extension of directly available energy resources and the development of alternative energy sources (Lee, 1989), susceptibility of the planetary biosphere towards waste can be discerned as the weakest link in the circular chain of sustainable global productivity. In order for today’s ‘resources’ to restore their original meaning (derived from Latin ‘resurgere’, which means ‘to appear again, to be born again, to renew’), the end link of the chain of global productivity needs to be taken gently to its beginnings and entwined into a closed loop wherein every form of ‘waste’ would become a source for the creation of something new.

It has been evidenced that the augmentation of human experiences by means of ever more complex human/technology interfaces often implies a distancing of human users from the origins of the utilised objects. For example, does an average newly married couple know that with buying a pair of golden wedding rings, the formation of a few tons of waste matter becomes initiated, as well as that 13% of the global SO2 emissions come from the production of gold from sulphate minerals (Worldwatch Institute, 2004). A symbiotic arrangement of the industrial production would naturally lead to an increased awareness of consumers about the origins of the utilised products. As such, it currently presents one of the strongest ideals favouring sustainable development on the horizon.

There are a number of examples of symbiotic industrial organisations, especially in the field of organic agriculture. In Colombia, a symbiotic interlacement of a coffee plantation, agricultural and poultry farms, and electrical generators produced an eco-industrial cluster wherein no resulting waste becomes generated. In Fiji, a diverse food industry comprising farms, ponds, hydroponic gardens and methane-producing facilities became symbiotically clustered in a similar way (Capra, 2002).

A network of industries in the Danish town of Kalundborg, wherein power plants, an oil refinery, a pharmaceutical plant, fishery ponds, agricultural farms and plants for producing cement and gypsum boards are symbiotically connected, presents a paradigmatic example of a spontaneous symbiosis of various industries. Production efficiency increased by 30%, savings of 30,000 tons of coal per year, and the prevention of emission of 1.3 million tons of wastes to the land and sea and 135,000 tons of sooth and sulphur to the atmosphere per annum have resulted from such a synergetic organisation (Chertow and Lombardi, 2005).

A significant consequence of the symbiotic approach is that it naturally imposes the necessity of optimising one’s management in accordance with a ceaseless reference to both the living environment and complementary industrial sectors. Such an approach may also strengthen an awareness of the given productive sectors as inherently belonging to the network of supporting social and ecological relationships. Maximisations of ecological sustainability and resource productivity would be, furthermore, considered as
inseparably entwined paths on the road to social and technological progress, metaphorically resembling parallel rails of a railway track or wings of a bird.

Examples of successful implementation of seemingly useless wastes as raw materials in various production processes are numerous. Uniqema has recently developed a method for the extraction of squalene from the waste streams of a near-by plant for producing olive oil instead from the endangered species of sharks, whereby Conoco has employed a procedure for transforming low-quality, waste tar into high-quality carbon fibres (Jenck, Agterberg and Droescher, 2005). The history of technologies, in fact, offers many examples of similarly lucid achievements. The primary syntheses of aniline dyes, phenol resins and aspirin from waste tars in the early 19th century initiated the formation of the first organic chemical industries (Ayres, 1989). Discovery of the methods for transforming natural gas (which was until the mid-20th century discarded as a waste chemical) into ethylene, butadiene and styrene as the basic ingredients of synthetic rubber provides another example (Ayres, 1989).

However, it may be reasonable to ask whether a perfect industrial symbioses and zero-waste society are attainable. There is a lack of ideas and technological solutions for the use of a plenty of waste materials that come from contemporary production processes, including many non-biodegradable composite products and uncontrollably dissipating by-products, let alone radioactive and other hazardous wastes. Therefore, instead of the ‘end-of-pipe’ solutions which correspond to merely detecting and tracing the toxic chemicals in the course of their unpredictable ecological journeys, the focus of the ecological research should be preventively switched to examining innovative ways to modify the chemical pathways inherent to the modern-day industrial processes. Many are examples (Duijvenbooden, 1998; Oxley and Allen, 2000) of unexpected and sudden increases in concentrations of toxic chemicals in the soil, ground waters and water basins, frequently occurring many years after the amplitudes in their environmental emissions were recorded. Such examples may indicate the current inabilities to perfectly deduce maximal doses of toxic chemicals that the environment can assimilate, as well as the necessity of quantitative-to-qualitative transitions in the ecological research (Tickner and Geiser, 2004). Green methods (Graedel, 1999; Haile, 1999; Tsoka et al., 2004; Warner et al., 2004) of processing that would more harmoniously interfere with the living environment might naturally result from such a transition.

Another problem is that the contemporary commercial products are frequently inappropriately designed for the recycling treatments. For example, the complex assemblage of multi-component systems, including composite materials, integrated circuits, electronic equipment and envelopes with plastic windows, produces many difficulties in the attempts of their recycling. Recycling is also disfavoured in almost all the cases where the material becomes dispersed into the environment during its use. This effect is notable in the examples of chlorofluorocarbons of the old refrigerators, paints that coat almost all the commercial products, cosmetics, detergents and fuels. In that sense, it may also be noted that the largest proportion of industrially employed heavy metals is of dissipative character (Ausubel, Frosch and Herman, 1989).

Nevertheless, it has been acknowledged that the first planetary forms of life (prokaryotic, single-cell organisms) produced energy by an unsustainable anaerobic fermentation of organic molecules, previously formed by geophysical activities in a non-oxygenic atmosphere (Ayres, 1989). The exponentially progressing informational growth of human civilisation has similarly begun with the unsustainable use of geophysically precipitated fossil fuels. However, sustainable innovations during the
evolutionary development of life brought about anaerobic photosynthesis, substitution of fermentation processes with respiration mechanisms, and implementation of the citric-acid cycle. Bearing this in mind, we might analogously conclude that similarly cyclical, zero-waste patterns of informational growth, reinforced by the employment of green chemical pathways of production and renewable energy sources, present beautiful carousels behind the horizons of the current stage in the development of human societies and the supporting ecological substrates.

3 Complexity of biotic relationships

Innumerable organisms and species, approximately 50–100 times the number of living species nowadays existing on Earth (estimated to between 4 and 40 million (United Nations, 2005)), have been providing the fertile ground for the evolution and development of human beings ever since. Many of these species are in an almost incomprehensibly subtle manner involved in maintaining the earthly ecosystems in sustainable interactive loops. Insects, birds and wind pollinate flowers; frogs, fish and birds naturally eliminate pests; oysters and other sea organisms purify sources of fresh water; fungi and algae sustain fertility of the soil; lichens, moss and ferns dissolve minerals from the attached rocks and create seedbeds which can absorb moisture and, as such, provide nutrients and foothold for higher plants; trees prevent land erosions, floods and droughts, produce rains, provide shelter, nutrients and building materials for higher life forms, protect the soil from the hammering force of raindrops, etc.

Biological diversity of ecosystems is directly proportional to their inherent flexibility, adaptivity and sustainability upon various internal perturbations and external influences. The cybernetic principle of requisite variety (Glanville, 1998), proposed by Ross Ashby, tells us that the larger the variety of actions available to a control system, the larger the variety of perturbations it is able to compensate. In the ecological context, it demonstrates how decreasing genetic diversity and migratory ranges (which, in large extent, amortised climate changes in the past), and supporting the trend of extreme centralisation of particular species could be distinguished as convenient effects concerning the attempts to predict and control the environmental feedback upon human actions, but as unfavourable trends in the context of reaching planetary sustainability. On the other hand, as the biosphere, the object of ecological scrutiny, becomes more complex comparing to human organisations, prognostic uncertainties and inabilities to perfectly control ecological interactions inevitably follow.

Should the current rate of the agricultural development (corresponding to the process of transforming naturally developing ecosystems into artificially cultivated fields) be extrapolated, the point where two-thirds of the biospheric soil would be converted into agricultural lands may be shown as immanent in the near future (Lovelock, 2005). In light of H.D. Thoreau’s principle that ‘in wilderness is the preservation of the world’ (Thoreau, 1994), natural abilities to preserve the chemical properties of soil in fertile conditions can be consequently regarded as seriously endangered in the long term. The failures of monocultures and other anthropomorphically oversimplified eco-blueprints to sustainably exist indicate that certain fragments of natural ecosystems should remain spontaneously developing areas within globally sustainable cultures. Impossibilities to perfectly predict the long-term consequences of human actions should prevent
short-sighted transformations of natural wildernesses and unknown relationships into over-designed ecological relationships and immaturely propounded certainties.

In general, the problem of sustainability can be, roughly saying, tackled from two different sides: top-down and bottom-up. Whereas the first corresponds to actions exhibited in relation to the hierarchical tops of human organisations, the latter approach would be more concerned with delivering appropriate incentives at the foundations of their functioning. Financial investments can be taken as an example of the former kind, whereas innovational and educational improvements of the existing systems would fall into the latter category.

It has been observed that, in accordance with natural phenomena in general (Bateson, 2000), the attempts to solve the problem of sustainability in political, hierarchical and so-called ‘top-down’ ways become at a certain point encountered with puzzling circular causal chains wherein each cause presents an effect and vice versa. It can be, thus, noted that in order for the problems of planetary poverty and famine to be solved, stable political and security bases should be set, for which good educational foundations are required, for which the solution of existential poverty becomes the necessary precondition (Churchman, 1968). However, a favourable feature of cyclical causal linkages is that exerting an influence upon any of their segments might present a crucial impetus in favour of their more harmonious spinning. In this sense, population balances, elementary education and economic, socio-political, cultural and technological aspects of the human civilisation have altogether recently been indicated as the fields upon which substantial changes need to be initiated in order to reach the targets of sustainable development and harmonious, globally progressing equalities (United Nations, 2005).

On the other hand, investing in the top levels of the reigning state institutions can be seen nowadays only as a single side of a successful approach to initiate equality and sustainability in the world. Small deeds, slender thoughts and direct humane contacts exhibit equally powerful incentives towards attaining a more harmonious order within world organisations. Without the latter, it is only fish, and not the art of fishing that is going to be provided to less developed societies, thereby only temporarily ameliorating the symptoms of a social and economic disorder. As the problem of inadequate education (which presents the hidden foundation of all the apparent problems within human societies) cannot be solved by simply relocating funds, varying economic and political parameters or sustainability indices, any approach not taking into account these minor but essential human-to-human interactions would present an incomplete path to a sustainable world. To reach the latter, it is crucial to foster the importance of direct human-to-human communications, open dialogues, active participation in decision-making and paying responsibility not to higher authorities only, but to the deep sense of ethics within our beings as well. In any case, as sustainability is crucially dependent not only on the level of technological eco-friendliness within a society, but on the social potential to maintain the existing technological infrastructure as well, the phenomenon of sustainability could not be by any means separated from its social and educational grounds (Tainter, 2006).

However, the very science standing at the basis of all the technological innovations supposed to get our civilisation closer to the ideals of a perfect sustainability is a social phenomenon in itself. Ever since Thomas Kuhn pointed out that

“the competition between paradigms is not the sort of battle that can be resolved by proof… as in political revolutions, so in paradigm choice – there is no standard higher than the assent of the relevant community” (Kuhn, 1969),
it became clear that the process of adopting certain scientific paradigms as the dominant ones has to be based on an understanding of the pragmatic applications of these same paradigms within the society as a whole. In fact, scientific descriptions reflect observer-independent features of natural systems in about the same extent as they reflect the initial assumptions made by the observer in the act of analysis and interpretation. Another argument may be given in support of this proposition, related to the nature of perception and abstract reasoning. Namely, every sensory organ is involved in reshaping the perceptive impulses of the environment in order to assimilate them to the cognitive needs, potentials and anticipations of the subject organism (Maturana et al., 1987; Glasersfeld, 1995; Poerksen, 2003). Furthermore, the latter constructs its own world of experience based on the perceived details at the level of abstract reasoning. Therefore, reaching the ideals of a perfect objectivity is an illusion, which explains why the modern philosophical streams largely nurtured on the schools of pragmatism, constructivism and second-order cybernetics naturally substitute the attribute of truthfulness (defined without a reference to the nature of the observer and community in which the meaning of science predominantly exists) with the one of pragmatic viability. Therefore, the needs and expectations of the society are the ones that in large extent define the actual progress of science at its most fundamental level. As science intertwines the biological nature and social needs of humanity with the propensities of the physical environment, a closed circle in which the society gives rise to scientific discoveries and technological products that in turn modify human conceptions about the world is formed.

Be that as it may, an enormous inherent complexity pervades all ecosystems. Thereby, it becomes impossible to distinguish constructive actions from disadvantageous ones in the long-term perspective based on merely analytical procedures of observing and reasoning. Viruses as intruders into either biological or computational systems have not led to the destruction of the attacked, metabolic and microprocessing networks, respectively, but have provoked their evolution into more safely organised, more adaptive, optionally diversified and inherently smarter systems. Likewise, the whole evolution of life has been based on the competitive co-evolution of species and individual organisms, which implies that a complete exclusion of the extraneous disturbing effects would lull the creative potentials of living beings. In this sense, it is important to note that the context of the whole, although it cannot be thoroughly grasped, partly defines the qualities of its constitutive systems and their mutual interactions. We may be, thereupon, reminded that ‘nothing is quite beautiful alone: nothing but is beautiful in the whole’ (Emerson, 2003).

In addition, identical natural patterns observed from different perspectives can be seen as endowed with thoroughly different qualities. Scientific concepts, therefore, present not truthful reflections of the natural order, but human concepts applied for the purpose of mutual coordination of human experiences (Glasersfeld, 2001; Romesin, 2002). Comprehended as such, many obscured relationships in the scientific arena would not be discarded as reflections of non-functional and useless segments of the natural order, as particularly notable in the case of representing 97% of human genome as ‘parasitic’ and essentially meaningless DNA sequences. In this sense, one thing is for sure: whereas uncertainties open the doors for novel insights and prospering of human knowledge (Medd, 2001), the attitude of fundamental sureness inevitably closes them.

Due to the effects of enormous complexity and sensitivity, the consequences of human actions upon the planetary organisation of life could not be deduced by means of pure logical reasoning (Boero et al., 2004). Some of the ineluctable weaknesses of the
models for estimating ecological footprints of human actions include the use of statistical methodology in which a finite number of either mutually independent variables or the ones interrelated in accordance with a set of oversimplifying approximations is assumed. All of this relates to the fact that an increase in the hypothetical interaction between the variables is inversely proportional to the probability of correctly predicting its future states. Because it is necessary to seriously simplify ecological simulations and models in order to enable their calculation feasibility, they are from the very start limited to an inherent population character (Medd, 2001). Simplicity of the conceptualisations inherent to the majority of models applied for depicting the interactions relevant for the subject of sustainability in large extent limits the applicability of their outcomes (Gallopin, 2002). In that sense, questions arise on how to pragmatically model a multi-layered complexity of interactions typical for the interaction between human organisations and the environment. In order to approach that aim, emergent properties, self-organisation phenomena and co-evolutionary feedback interactions need to be integrated with human values, undoubtedly involved in shaping the patterns of human creativity (Gallopin, 2002). In view of that, however, scientific rigorousness should not be relaxed by means of mingling it with a dose of holistic intuitiveness, but quite contrary: it should impose an even more rigorous role, although with an inevitable balancing of analytical and integrative skills (Gallopin et al., 1999). Although, in the end, as even these models would not be able to provide a complete picture of the studied phenomena on the eco-scale, final decisions relevant to the subsequent design of sustainable human interactions would need to fall into domain of a well balanced computational knowledge and intuitive skills, ideally based on refined ethical and aesthetic criteria.

A compromise between the use of strict quantitative models (that always rest on oversimplified initial assumptions and measurement problems, appearing as the result of enormous complexity of the biosphere) and qualitative, systemic and metaphoric patterns of reasoning (as reflected in the analogical aspect of reasoning that has ever since been the essence of human wisdom) should comprise a necessary precondition for decision-making processes in sustainability frames. The importance of including wide ranges of both expert and ordinary opinions in inter-disciplinary networks of problem-solving approaches should not be underestimated. We should be reminded that Rockefeller University, which is not divided to specialised departments, but instead instigates a unified, interdepartmental approach to research, presents the institution from which the largest portion of the recently collected 291 major scientific breakthroughs from the history of science originates (Hollingsworth, 2004, 2007). Encouraging a diversification of opinions and proliferation of a variety of worldviews presents one of the essential ingredients of the deep ecological ethics (Naess, 1992; Lubchenco, 1998). On the other hand, valuing a wide-contextual framing of research efforts and achievements, regardless of their apparent magnitude and meaning in the web of life, presents another essential quality of the long-range sustainable assessments.

In the original setting of the movie ‘Twelve angry men’, Henry Fonda as the juryman Davis saves a boy’s life by promoting an attitude of uncertainty as opposed to the socialistic and unquestioning worldviews of the fellow jurymen. Many lives may be accordingly saved today by dignifying the attitudes of uncertainty, dubiety and questioning, in contrast with the propagation of cognitive stances based on absolute certainty, predictability and non-revisionary resoluteness. Similar to all the essential balances in the living world, the compromise between the predictive and uncertain character of relationships between humanity and the environment does not possess a
potentially stable and permanent basis, but presents a mutually accentuating and dynamically evolving encounter of opposites.

4 Examples of sensitive environmental cases

Many examples may be provided for the sake of highlighting the cases where apparently negligible and typically overlooked ecological effects subsequently become revealed as some of the key influences for the conservation of ecological balances. It was, for instance, discovered that the primary reason for a decrease in a population of sea turtles lay not only in lingering on the official decisions whether to include special openings for them in fishermen’s nets, but also in the fact that enormous amounts of artificial light were confusing the turtles, and instead of swimming towards the moonlight, they were being self-guided ashore and beached. In Ivory Coast, Ghana and Liberia, specific species of trees ceased to regenerate after a massive extinction of elephants, upon whose spontaneous transmission and digestive fertilisation of seeds they inherently depended. Unique colonies of sea worms and other invertebrates from the sea depths currently suffer a decline in population due to a decrease in the number of natural whale deaths, upon whose remains (used as food) they depend (Tuxill, 1998).

The planting of a supposedly superior variety of coffee plant, more resistant to sunlight, led to an extinction of numerous migratory bird species to which otherwise existing shadowy shrubs and trees provided essential stations in their seasonal migrations (Tuxill, 1998). In general, replacements of natural forests with plantations as homes to either monocultures or poorly diversified sets of species have been frequently leading to unpredictable fires, soil erosion and floods (Lowdermilk, 1939). Improper grazing or natural disasters at even comparatively small areas have on many occasions induced unforeseen destructive consequences spread thousands of miles in radius through a chain of subtle effects. Such is the example of the White River National Forest in Colorado wherein a windstorm simply deflected a group of spruce trees, tangled their branches and made bark beetles inaccessible to woodpeckers (Storer, 1953). The beetles eventually multiplied and in a few years devastated large portions of the forest, made it susceptible to droughts and fire, subsequent floods, destruction of the top soil and its erosion until sterile rock or sand base of a new desert has appeared. It has been observed that the eradication of natural weeds (as performed in industrialised agrarian fields) leads not only to an unbalanced proportion of organic and mineral nutrients in the soil (which the appearance of weed is a natural response to) and the consequent disruption of the local eco-cycles, but also to a reduced resistance of such interrupted ecosystems to pests, droughts and salinisation. Due to unsustainable agricultural practices, approximately 1.2 billion hectares of once fertile land was transformed to permanently non-arable soil during the last half a century (Friends of the Earth International, 2001).

Not only does the idea that desired and useful outcomes of any production process can be discerned from the by-product wastes not hold, but also the idea that it might be possible to store waste with a perfect efficiency (that would ensure that they could be practically forever kept inside the confined spaces) presents an untenable conception as well. Due to the dissipative structural organisation of biological entities and the continual biospheric cycling of the basic atomic and molecular ingredients of life, various industrially produced chemicals can be detected even at the remotest and virtually intact places on Earth. Hence, the penguins from Antarctica and a family of albatrosses
that dwells in the ocean depths and breeds on the coral reefs of the central Pacific, contain approximately equal concentrations of Dichloro-Diphenyl-Trichloroethane (DDT), Polychlorinated biphenyls (PCB) and dioxin derivatives as the eagles flying across the skies of the US industrialised cities (Gardner and Sampat, 1998). Therefore, as observed from the perspective of resource conservation, depletion of non-renewable resources is not as significant obstacle to the development of sustainable technologies and industrial networks as a reduction in productivity caused by the interference of the waste of the modern-day industrial facilities with naturally regenerative sources that drive human civilisation (Schumacher, 1998).

However, it is important to note that the natural cycles of matter at the biospheric scale are threatened not only by the release of wastes, but also by an exorbitant interference of human actions with them. Therefore, the modern-day unsustainable practice is reflected not only in the alleged fact that a few planet Earths would be required to satisfy the global consumption averaged to the current habits of an average North-American person, but also in the fact that the flow of matter as induced by humans today exceeds the natural flow of matter by the factor of two (Gardner and Sampat, 1998). Unpredictable consequences for the climate, including a withdrawal of the ground waters upon which more than a half of the planetary agricultural yields depend, have resulted from the latter imbalance. As such, the quantities of drinking water (being the result of the natural purification cycles that distil water through evaporation, condensation in form of clouds and falling back to the earth as purified rain) have been diminishing not only because ‘clean’ dishes and house interiors exist at the cost of polluted rivers and seas (Capra, 1982), but also due to an excessive depletion of renewable water sources at a rate faster than the rate of their natural regeneration. Therefore, as the models of perfectly harmonious human/ecosystem interfaces could not be depicted even when no permanent waste is produced, predictions of the environmental feedback upon human actions and the design of sustainable patterns by reliance on merely empirically-analytical procedures inevitably produce imperfect outcomes.

The major anthropomorphic causes behind the extinction of numerous planetary species are not related to apparently more significant and drastic influences, such as environmental emissions of toxic chemicals and intensification of the atmospheric ‘greenhouse effect’, but appear as the result of subtle effects following permutations and fragmentations of habitats of the living species (Solé et al., 2004), their utilitarian exploitation, and the accidental introduction of foreign and invasive species into the ecosystems of concern (Tuxill, 1998). In addition, extinction of the most outstanding predatory species, such as wolves, lions, coyotes, sharks, whales, tuna and bears (Boero et al., 2004), has led to ecological deviations that threaten to rupture essential relationships among various species, including the ability of the biosphere to support any higher form of life. The famous record of Kaibab forest in northern Arizona may provide an example of devastating effects produced by human interference with predator–prey relationships on the basis of oversimplified ecosystemic models (Storer, 1953). Namely, in an early 20th century attempt to restore the low population of deer, their predators including wolves, coyotes and mountain lions were systematically eliminated. Eventually, instead of restoring the number of deer to a desired level, the herd increased in size far above the carrying capacity of the range. The forage on the range subsequently became seriously damaged, which further lessened its carrying capacity and initiated dropping of the number of deer to its initial value, although eventually existing on the fields of significantly degraded ecological richness. Another interesting example is
related to the recent observation of acacia trees in an East African Savanna as more fragile and less susceptible to disease when enclosed by an herbivore-deterring electric fence than when exposed to their natural predators, including elephants, giraffes and antelopes (Palmer et al., 2008). Namely, these Acacia trees form a natural symbiosis with different ant species that protect the trees from mammalian herbivores, whereas the trees grow hollow thorns in which the ants shelter and exude nectar on which the ants feed. However, without the natural exposure to predators, acacias cut back on the density of thorns and nectar-producing glands, and the ants descend down raising herds of insects that pilfer the precious tree’s sap that is a scarce resource in the dry habitat in which the trees reside. In addition, a single ant species eventually took over the entire enclosed acacia habitat, ending up the natural competition between at least four different ant species, and rendering the trees strikingly less resistant to the attack of wood-boring beetles.

Likewise, the effects of genetically modified foods on human consumers could not be perfectly evaluated, primarily because they do not exhibit direct effects on the consumers (as all the absorbed proteins from food become hydrolysed to individual amino acids by the action of specific enzymes of the digestive tract, whereas the difference between the natural and genetically modified food lies merely in the sequence and content ratio of the constitutive amino acids), but can only indirectly affect human users through inducing disrupting changes in the ecological cycles. The latter can be expected in view of genetically modified crops being artificially introduced species and not the ones formed by the natural co-evolution.

Various cases of DDT usage wherein unexpected immunisations of the targeted insects or disruptions of life-supporting ecosystemic loops occurred were recorded (Bateson, 2000), but one particular example (Lovins, 2002) seems to be especially striking. Namely, applying DDT sprays with the aim of preventing the spread of malaria in a Borneo community induced the extinction of a parasitic wasp that had previously balanced the population of thatch-eating caterpillars. With the population of wasps diminished, the thatch-eating caterpillars began eating the thatched house roofs, causing them to cave in. Furthermore, DDT-poisoned insects were normally the food of geckos, whereby these lizards were the food of cats. The population of cats eventually started vanishing, and in order to prevent the uncontrolled spread of rats and the consequent outbreak of typhus and plague, the World Health Organisation finally prescribed the parachuting of 14,000 live cats.

Contrary to simple, desktop-fitting ecospheres distinguished by their general stability, but unpredictable development of the comprising species (Kelly, 1994), Biosphere 2, the attempt to produce an artificially arranged ecosystem (opened only to sunlight) as home to human beings as well ended up in oxygen levels reduced below the limits for sustaining the inherent biodiversity (Thomas and Assadourian, 2003). The critical point in the transition between the well-functioning and unsustainable ecosystem in this case seemed to have been triggered by a succession of minor events, supposedly related to an overemphasised engagement of the crew members in the process of manual weeding of the constituent plant species (Kelly, 1994).

At the rise of their massive implementation, hydrothermal power plants seemed as wonderful means for transforming geological streams of water into electricity. However, radical shifts in the organisation of local ecosystems were later observed, including the blocking of natural fish migrations and downstream movement of nutrients, changes in velocity, temperature, water level and oxygen content of the water currents, and increase
in water salinity following the evaporation of water basin contents (Brower, 1992). Minor changes in quality of the water were evidenced as triggers of significant modifications and possible reductions in biodiversity of local and distant aquatic ecosystems alike, including the supporting communities (Storer, 1953).

Thalidomide drugs ‘successfully’ passed the tests on animals, but left tragic consequences on pregnant human users and their progenies. The ideas of using fluorinated hydrocarbons in refrigerating appliances were readily received as an excellent solution for the problems related to utilisation of combustible ammonia, methyl chloride and sulphur dioxide for the same purpose. However, that excitement lasted only until their disintegrating effect on the stratospheric ozone layer was discovered half a century later. On the other hand, neither the problems of global heating nor thinning of the ozone layer found their places on the agenda of the first Conference of the United Nations on global environmental conservation in Stockholm in 1972. Likewise, the unforeseen nine-fold increase in the number of natural disasters (Annan, 2000) between 1960 and 1990 presents another reflection of intrinsic inability to predict the consequences of human actions on the basis of purely empirical and analytical schemes of reasoning.

Despite the fact that it has been widely argued that serious reductions of anthropomorphic emissions of molecular species that transform sunlight to infrared heat would solve the problem of global warming, the situation is not that simple. In fact, due to non-linear relationships between all the corresponding ecological factors, the causes of global warming cannot be analytically dissociated into separate human, ecological, geological and astronomical influences. We have already discussed the fact that even if the total industrial waste would be transformed into appropriate resources, an unbalanced rate of the use of natural resources might present an inherently unsustainable practice. Therefore, similar as the absence of artificial pollution does not necessarily imply sustainability of the technological progress, a stabilised level of artificial CO₂ emissions may not inevitably lead to stable planetary surface temperatures and weather conditions in the future. It has been evidenced that planetary ecological cycles include continual natural emissions of CO₂ into the atmosphere (as through volcanic eruptions, for instance) as well as its continual precipitation through the natural processes of soil erosion and sedimentation (Lovelock, 2005). These two processes have not been, in fact, precisely compensated throughout the history of the planetary life, but have always varied in harmony with biotic interactions and the evolutionary steps of life (Gorshkov et al., 2004). The transition from reductive to oxidative atmosphere that occurred approximately 2.5 billion years ago (in concert with the emergence of photosynthetic organisms) could present an example of such a mutual regulation of biotic and abiotic factors. The evolution of life may be correspondingly depicted as proceeding through neither neo-Lamarckian passive adaptation of organisms to environmental constraints nor neo-Darwinian random genetic changes within individual organisms, independently of environmental conditions, but through a co-evolutionary, mutually changing and optimising dance between all living and non-living planetary elements. The greenhouse effect is, in the similar manner, primarily controlled by global biotic processes that through complex networks of subtle effects regulate movement and distribution of water, the major greenhouse substance which produces both heating (in form of radiation-absorbing water vapour) and cooling (in form of light-reflecting clouds) effects upon the atmospheric heat content.

The ‘butterfly effect’ holds a special place in the science of complexity and presents a splendid example of the enormous sensitivity of the final outcomes of spontaneously
developing ecosystems upon the smallest and uncontrollable changes in their initial conditions (Gleick, 1987). It might also invite us to rethink the primary initiations of our actions and footprints in the world. Because

“not dictators, armies, and police forces, but the changing values and ideals of people are the butterflies that, flapping their wings, determine which way society will grow and develop; it is up to each of us to flap our wings and to launch our bifurcating societies along a humanistic evolutionary path” (Vögler, 2001), as Ervin Laszlo stressed out.

On the other hand, ‘the democratic world probably cannot survive its own implications without rethinking its axioms’ (White, 1967), Lynn White claimed at the end of his famous and in many respects pioneering *Science* paper on the roots of the actual eco-crisis. But how deep do these axioms extend? Do they end at the presupposed basic biological relations that support human civilisation, or they get hold of the fundamental tautologies of our reasoning? Do they reach implicit patterns of our most elementary ideas, or maybe even touch our deepest aspirations, anticipations and values that provide the phenomenological bases of our perception, reasoning and action in the world? How deep are we prepared to tread in rethinking these axioms, may present the crucial question for the current stage of social and conscious development of humanity.

5 Return to the importance of being small

One of the natural side effects of the preceding discourse is the return to appreciation of small things, small actions and small achievements, as embodied in the famous E.F. Schumacher’s slogan ‘Small is beautiful’ (Schumacher, 1998), and in contrast with the contemporary fascinations with size, massiveness, spectacular events and populism. As we could have seen by now, in a highly complex, non-linear world that we inhabit, it is not always the case that big deeds produce all-encompassing effects and small actions leave negligible traces. Sometimes apparently large and important things disappear under the slow pace of time, whereas momentarily small and almost invisible deeds might be proven to be of an enormous significance after all.

However, we still seem to live in a world in which the ideals of observing greatness in impalpably small are almost non-existent. The contemporary informational media orient people towards big events upon which ordinary men can have almost no influence at all, whereas small and proximate occasions where people can immediately begin to participate are left out of sight. In addition, big ecological events, such as ocean outpouring of oil tankers’ contents withdraw attention from small, but incrementally more drastic similar effects, despite being known that for each mistakenly outpoured ton of oil, another twenty tons are being released within everyday oil transportations (Schumacher, 1998).

The popular ecological imperative to ‘think globally, act locally’ might be from this perspective regarded as comprising an additional implicit message. Broadening the context of natural patterns in ecological conceptualisations, in terms of seeking for an ever larger Gestalt to keep in the small deeds of humanity, presents one side of the attitude that this work has expounded. Our devotion to observing unique and essential significance of minute thoughts and deeds for the development and sustainability of natural order presents the other complementary side. The idea that every local act
possesses an immediate global significance and vice versa – that every pattern of the
global order becomes incessantly reflected on the qualities of immediately observed
natural systems – becomes crystallised from such a polar cognitive perspective.

In accordance with the aim of this work, set forth in the opening section, the ideals for
the development of the global society may not need to either abandon modern
technologies or blindly follow the preconceived course of scientific progress regardless
of the natural constraints. We are finally arriving at a common ground that harmoniously
balances the technological, economic and societal development with the stewardship of
biodiversity.

Each industrial product on the market presents only ‘a tip of the iceberg’ in relation to
the overall processing pathways that have given rise to it. With acknowledging the
importance of these processing foundations, superficial concerns over the ‘end-of-pipe’
effects would be transformed to interests in modifications of industrial processing
networks on their very bases. However, one of the major obstacles to the implementation
of intrinsically ‘green’ synthesis and processing pathways is related to the fact that
contemporary chemical industries rely on heavy capital and are, therefore, in large extent
inflexible to introduction of technological innovations. Yet, recall that the evolutionary
progress in complexity of biological systems has not implied the growth of their inherent
units (i.e. cells), but a series of advancements at the level of complexity of intracellular
metabolic patterns and cellular interactions with the environment. Likewise, a transition
to the sustainable industry of the future might not correspond to an increase in size of the
production facilities and enterprises, but to a formation of complex networks among
ecologically more viable, more process-efficient (as analogously related to superior
computational efficiency of parallel computational networks in comparison with highly
centralised, serial computers (Kelly, 1994)), and socially more adaptable (concerning
the potential for transfer of technologies and know-how (Hassan et al., 1984)), small,

The actual visions of scientific progress, in fact, offer many options for contributing
to sustainable development, and that again mainly in the domain of ‘nano’, which
Ultra-fine design of materials enables fabrication of devices with more pronounced
functional efficiencies comparing to their older counterparts. For instance, carbon fibres
can nowadays support constructions with an order of magnitude larger weights
comparing to metallic materials used for the same purpose two centuries ago, whereby
fluorescent lights are three times more energy-efficient and ten times more durable in
comparison with tungsten bulbs (Worldwatch Institute, 2004). However, increased
efficiency (that the contemporary ecological R&D is mostly devoted to (Tsoka et al.,
2004)) normally stimulates the economic growth, and rarely leads to a reduced
consumption of resources. Also, short-term efficiency has been frequently introduced at
the cost of diminishing recycling capabilities and long-term sustainability. Innovative
transitions from open to oxygen furnaces in the production of steel, and the replacement
of heavy, although easily recyclable automotive pieces made of steel with lighter, but
hardly recyclable plastic composites may be some of the examples (Frosch and
Gallopoulos, 1989). Fluorescent bulbs, furthermore, compensate their energy efficiency
by containing large amounts of plastics, mercury, lead, tin and circuit boards (all of
which the older iridescent bulbs have not had), which makes their recycling a difficult
effort. In any case, scientific and technological progress conducted with respecting and
nourishing its supporting ecological environments presents an optimistic perspective for
the sustainable advancement of our knowledge. But quite blessings and hopes that all that we do now will somehow turn out good tomorrow could present an equally important aspect of this path. Or as H.D. Thoreau wrote,

“If the cloud that hangs over the engine were the perspiration of heroic deeds, or as beneficent as that which floats over the farmer’s fields, then the elements and Nature herself would cheerfully accompany men on their errands and be their escort” (Thoreau, 1986).

6 Conclusions: back to the foundations with science and common wisdom as hand-in-hand

‘We reap what we sow’ presents the ultimate message of all the traditions of wisdom within the human civilisation. As the aforementioned rain-forest elephants, it might be that we too are by stepping through the jungle groves of rational planning and designing of tomorrow’s technologies, economies and cultures inconspicuously sowing the invisible seeds that keep the secret of sustainable development and future blossom of our today’s marvellous work. These inexplicable secrets may be indefinable by relying on pure analytical measurements and logical conceptualisations. In order to dig down the stems of human idealisations and reach the sprouts that correspond to the very initiations of our actions in the world, the study of allegorical messages of the profound scriptures that comprise the threads of the traditions of wisdom of our civilisation presents one of the paths that might be taken. Return to the foundations of our thinking, planning and creating could, therefore, present a true way forward.

However, as there is no universal design for the assessment of sustainable actions, there is no recipe for collecting absolutely certain insights into the quality of seeds that become sown with our apparent actions. One such quest for the sustainable solutions of the evolving human/technology interface would inspire scientists and laymen alike to look for the harmony between analytical thinking and holistic world-views. In fact, if scientific, theological and artistic expressions are all conceived in a pragmatic manner (i.e. not as fundamental(istic) and objective images of the world, but as metaphorical concepts used for a mutual, co-evolutionary coordination of experiences), their mutual incompatibilities could become transformed into relationships of complementary accentuation and support. For example, the word ‘science’ originates from Indo-European *skei*, which refers to ‘making a difference’, whereby the word ‘religion’ derives from Latin *religare*, which means ‘to connect’. Drawing differences where there were unisons by applying scientific reasoning, therefore, contributes to the informational enrichment of human worldviews and the Earth itself. But the perception of meaningful wholes where seemingly dismounted manifolds resided by means of holistic experiences contributes to cultivating an inner sense of the divine existential purpose. In balancing the two approaches to a mindful and creative relationship between men and Nature, the doors to the fields of sustainable harmony open. Only through the way of harmony between intellectual rigor on one side and inner love and blessings for our deeds on the other, is that we will find the way towards truly sustainable interaction between humans and Nature, and bring forth the fields of bright future for our children.
References


