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RISK OF GLOBAL COLLAPSE AND NEW APPROACH TO SUSTAINABILITY CONCEPT

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Despite great promise of sustainable development concept, the reality is an accelerated destruction of life support systems and overshoot of several of the Earth´s ecological boundaries. Taking into account also a non-equlibrium thermodynamics of living systems, a sustainable retreat seems to be a better alternative. The premise that sustainable society should live within the ecological and social boundaries lead us to improved sustainability concept and indicator.

Key words: sustainability, ecological boundaries, ecological and social integrity.

РИЗИК ГЛОБАЛЬНОГО КОЛАПСУ І НОВІ ПІДХОДИ ДО КОНЦЕПЦІЇ СТАЛОСТІ

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Не дивлячись на великі сподівання, що покладалися на впровадження концепції сталого розвитку, в реальності спостерігається деградація систем, що підтримують життя, і постійне розширення та перевищення певних екологічних кордонів Землі. Приймаючи до уваги нерівноважну термодинаміку живих систем, сталий розвиток може бути реальною альтернативою насьогодні, а, відповідно, суспільство має функціонувати в межах екологічних і соціальних кордонів, має сприяти покращенню впровадження концепції сталості та пошук і застосування відповідних індикаторів оцінки сталості розвитку.

Ключові слова: сталість, екологічні кордони, екологічна та соціальна цілістність.

PROBLEM STATEMENT. Sustainable development (SD) concept at the time of its birth had brought a great promise of joining economic and social development with protection of environment. It led to development of robust international environmental laws, innovative technologies and widespread environmental education.

Despite these achievements we face a loss of biodiversity at a rate unprecedented in human history, accelerating climate change, pollution and exhaustion of natural resources, etc. The planet is closer to the edge of ecological collapse than it was 25 years ago. Therefore, it is time to look on the conventional SD concept more critically – once the system boundaries are overshooted, retreat to shrink athropogenic pressures may be the right alternative to renew Earth´s ecological integrity.

Scientific evidence is mounting that during the last 40 years the erosion of life-support systems has speeded up. According to IUCN, from 63 837 evaluated species 19 817 (31 %) were listed as threatened – e.g. 1 140 (20,7 %) of mammal species, 1 313 (13 %) of bird species, 1 931 (30 %) of amphibian species, 375 of gymnosperms (39%) [1]. The Living planet index based on monitoring of 9 thousand populations of 2 688 vertebrate species has declined by 28 % between 1970 – 2008 [2]. The current rate of species extinction is 100 – 1000 times higher than the natural one [3]. The basic destructive processes include habitat liquidation and fragmentation, sharp changes of biogeochemical cycles, intoxication of trophic chains by synthetic chemicals, overuse and exhaustion of populations and ecosystems, biological invasions and climate change [4, 5].

Others alarming overshoots of the global ecological boundaries include climate change, esp. growth of CO_2 concentration in the atmosphere – reaching 391.57 ppm in 2011 [6], compared to its preindustrial level of 280 ppm (39,85 % increase) and disturbance of nitrogen cycle; conversion of the atmospheric nitrogen into its reactive forms is overshooting a proposed boundary 3,47 times and leads to increased eutrophication of river networks, lakes and seas [7]. Close to ecological limits are other processes: disturbance of phosphorus cycle, ocean acidification, land use changes, freshwater use, stratospheric ozone layer depletion, atmospheric aerosols, chemical pollution. This results also in a decrease of ecosystems capacities to provide services for humans – 60 % of the 24 ecosystem services are disturbed [3].

Method used. We provide three arguments on inadequacy of the conventional SD concept. The first one is based on confrontation of nine principles of the famous sustainable development strategy Caring for the Earth [8] with global environmental trends. The second one is based on the thermodynamic theory of ecological systems [9] application to sustainability and the third is a moral argument. Building on the non-equilibrium thermodynamics of living systems and on the model of social-ecological system [10] we have adjusted the sustainability concept to actual pressing challenges – leading to sustainable retreat – and we have proposed also a new aggregated sustainability indicator.

MATERIAL AND RESULTS OBTAINED. *Caring for the earth vs. 25 years of reality.* Summary of the results of comparative analysis of nine principles of this strategy with real trends is in Tab. 1.

Table 1 – Principles of the strategy Caring for the Earth (IUCN 1991) vs. enviro. trends 1992–2012

Principle	Original goal	Clearly positive trends	Clearly negative trends
1. Ethical – Respecting and caring for the commun. of life	Ethical obligation exist of respect and care for non-human forms of life and for life on the Earth as a whole.	Dudley: „*Most people also believe that we have an ethical obligation to prevent species loss due to our own actions*" [11] – inherent ecoethics.	Fundamental human values such as love, compassion, responsibility, are replaced by instrumental ones – effectiveness, profit, etc. [12].
2. Improving the quality of human life	Each human has right to a life of dignity and fulfillment, to live in freedom, security, good health, get an education. Everybody has right for access to education and to natural resources essential for a decent standard of living.	The number of extremely poor people (income 1.25 USD/ day) dropped from 1,8 to 1,4 billion in 1990–2008 [13]. Access to basic education in developing world has increased from 83 % of people in the year 2000 to 87 % in 2007 [13].	In 1990-1992 there were 848 million of undernourished people, in 2008 even 850 milllion – this millenium goal was missed [14]. Proportion of slum dwellers decreased from 46 to 33 % (1996–2010), but their numbers rose from 656 to 827 mil. [15].
3. Conserving the Earth's vitality and diversity	There is a necessity to protect life sustaining systems of the Earth and its biodiversity. It is necessary to protect biodiversity on all levels: species, genes, ecosystems. Necessity to safeguard sustainable use of renewable resources.	The proportion of protected areas on continents increased to 13 % (although of different quality) [16]. Comprehensive Strategic plan for biodiversity for the period 2011–2020 with 20 aims [17]. In 2010 there were 10 % of forests managed on the basis of ecologic. certified production [15].	High proportion of threatened species, e.g 21 % of mammal species, 30 % amphibians [1]. Decrease of the global Living planet index in the period 1970–2008 by 28 % [2]. Around 300 million ha of primeval forests were deforestated since 1990 (13 mil ha per year) [18].
4. Minimization of non-renewable resources depletion	It is necessary to decrease extraction of non-renewables, increase effectiveness, recycle, reduce consumption.	Effectiveness of resources use per unit of production of goods or services is rising, however consumption is increasing [15].	Rise of minerals extraction by 60–80 % in 1992–2005, rise of cement and steal production by 170 % and 100 % till the year 2010 [15].
5. Keeping within the Earth's carry-ing capacity	There are definite limits of Earth´s ecological carrying capacity and these should be strictly respected.	There exist around 500 internation. environmental treaties, number of signatories of the 14 most impor-tant increased by 330 % [15].	In 2008 the global ecological foot-print was 18,2 mld gha (2,7 gha /person), while biocapacity was 12 mld gha (1,8 gha /person) [2].
		The awareness of importance of ecosystem services and attempts to value them are rising [3, 17].	Three of nine Earth´s ecological boundaries are overshooted and remaining six are approached [7].
6. Changing personal attitudes and practices	SD initiatives and projects, educational, awareness, eco-nomic tools need support.	Significant rise of the issues of environmental ethics since the 80-ties of the 20 century [19, 20].	The public opinion manipulation by media, PR agencies and green-washing is growing [21].
7. Enabling com-munities to care for their environment	Passing competences to municipalities increase flexibility of protection.	The participatory approach in protected areas is promoted and globally growing [11].	Global erosion of middle social class & marginalization of local communities already visible [22].
8. Providing a nat. framework for inte-grating developm. and conservation	Monitoring, information, education, environmental law, education, integration of SD into economic sectors, etc.	Participation of women in jobs and politics, rise of women in national parliaments by 60 % between 1997–2010 [15].	Growing power of multinational corporations and their state support reduce space to protect nature and to care for environment [22].
9. Creating a global alliance	Mutual support and more justice in use of resources and solving problems is needed.	Network of actors, e.g. ICLEI connects 570 milllion people promoting local SD agendas.	Enormous rise of ideological think – tanks acting against protection of environment is recorded [23].

Positive trends include improved mainly quality of human life, development of environmental law, more protected landscapes and seas, ecologically certified production in forestry, agriculture and tourism, as well as many technological innovations to produce goods and services with less energy per unit of production.

However, from the point of Earth´s biodiversity and vitality, destructive processes have accelerated. This is documented also by an indicator of the changes of anthropogenic pressure: in 2008 the global ecological footprint was 50 % higher than the global biocapacity [2]. Similar conclusions were provided by Turner, who confronted reality of 30 years since 1972 with the prognoses of the famous global computer models [24]. According to his data analysis humanity follows their worst scenario [25]. And the pressure of driving forces of the planetary overshoots is more or less continuously growing – mainly overpopulation, overconsumption, poverty, injustice, wrong institutions, etc. [3, 5].

The harsh statistics of the state of the Earth bloom 25 years after the SD concept was introduced and 20 years after the UNCED – Earth Summit in Rio, where this concept was approved on the highest political level. Several scientists even proposed a new geological era of the Earth – The Anthropocene [26], starting at dawn of Industrial revolution, as anthropogenic changes on the Earth currently clearly dominate in changing its surface.

Thermodynamic theory and SD concept. According to the theory of non-equlibrium thermo-dynamics of ecological systems the same basic organizational principle penetrates all the system hierarchies and enables integration of lower systems into higher ones [9], e.g. organels → cells → tissues → organs → organ systems → organisms → populations → communities → ecosystems → landscapes → ecoregions → biosphere Development of a complex hierarchy and behaviour is system´s structural and functional response to more or less continuous input of high quality energy (exergy). And structural and functional complexity reflects amount of the energy coming into a system and dissipated by it [10]. Indeed, ecosystems throughout Earth demonstrate that if their abiotic factors, natural disturbances and land use are the same (or highly similar) then ecosystem´s structure and behaviour complexify towards lower latitudes, where they receive more solar energy.

This implies also that ecological balance of an ecosystem, landscape or ecoregion results from such a development which consists of building complex dissipative structures, processes and feedbacks, highly capable to grasp and transform available exergy. The ultimate aim of this is to develop and safeguard:

1) complex physical structures (e.g. distribution and interactions of species, ecosystems, landscapes);

2) complex functional patterns and system emergent properties resulting from interactions of its elements (including ecosystem services and life support systems);

3) life cycles allowing simultaneous development and changes of structures and patterns and their bonding – integrating through complexifying spatial-temporal order. (Compare to Capra´s model of life [27].) If a particular ecological system is unimpaired both from structural and functional point of view and keeps its natural order, it means it is fully ecologically integrated.

Analogically, as organism complexity rises towards its maturity, ecosystem complexity is higher in later stages of ecological succession, in which it dissipates more energy [28]. This can be demonstrated by means of the measurements of radiation balance at ecosystem surface and calculation of the efficacy of the solar energy dissipation by this ecosystem [29] – to which we tried to contribute also in our field experiments [30].

According to non-equilibrium thermodynamics, the succession driving force is based on maximum power principle [9], spontaneous development of more complex and efficacious dissipative structures, capable to cope with accumulation of energy in biomass More high quality energy in ecosystem drives changes of species composition and also trends of higher specialization (culminating in a climax). These processes lead to high complexity of living systems and are unsepparable from the production of entropy [31], which is expressed mainly by emissions of low quality, long wave heat radiation from the organism´s or ecosystem´s surfaces.

The generator of ecosystem complexities are non-linear interactions among its species, which results in a complex ecosystem dynamics, including oscillations of its elements, e.g. oscillations of local populations within boundaries of its predator-prey subsystems [32]. When approaching an ecosystem carrying capacity threshold the oscillations grow in size and in case of its overshoot (as is the current situation of our planetary ecosystem) they are so big that even minor further perturbation may lead to abrupt transition of a living system from one equilibrium state (or a sequence of quasi-equilibrium states) into a different one [10], changing both its physical structure and functional pattern. This means that any further development beyond currently strunged Earth´s boundaries is not sustainable. On the contrary, it increases a risk of abrupt transitions to unknown system equilibrium states with unforeseen consequences.

An important analogy exists also in the sphere of social systems [33]. It is no accident that megacities rocketted just in the Industrial age, mainly since 1950. Complexifying of western cities and high average affluence of their inhabitants was due to intensive use of fossil fuels (esp. oil). This enormously high input of energy into socio-economic-ecological system led to a growth of its complexity and to megacities. However, fossil fuels are non-renewable resources and they face the risk of depletion. It is not so important when exactly we will pass the peak oil as it is important that when it comes it will end era of a relatively cheap energy from oil on which industrial societies built their prosperity. As high ecological and social complexity is regarded as a response to high input of energy (and to a relatively stabile environment) then a sharp decrease of available energy will sooner or later lead to change of our socio-economic-ecologic structures and behavioural patterns.

The third argument is a moral one. Despite high average standard of living, mainly in industrial western countries, we did not develop a model suitable for the global society. Today there are more than 1.3 billion extremely poor people (850 million undernourished) [14]. While the poorest 20 % of the world human population have at their disposal only 1.5 % of the world income, the richest 10 % take on 54 % of it [34]. If all of the Earth inhabitants strive to achieve average standard of the EU citizens, we would need almost 3 planets like the Earth to satisfy people´s needs for food, shelter and energy. And more than 4 planets will be needed if all the people decide to achieve the USA living standard.

This way is unsustainable and leads to disintegration of the biosphere. In fact, the idea that infinite economic growth will bring general prosperity and peace was questioned decades ago not only by ecologists, but by a number of authors from other disciplines, mainly by economists, sociologists, psychologists, philosophers and others – e.g. [19, 20, 35–38]. Although their approaches and their life philosophies differ, the common line of their studies points to deep connection between ecological and social disintegration and they are concerned not just by deepening ecological crisis but even more by on-going cultivation of egoism and greed, which accompany the modern way of life. Majority of these authors claim necessity of more modest life, based on free, but well informed and also demanding human choice – giving high priorities to healthy environment and to sound human relations.

Sustainable retreat as a way to renewal of integrity. Apart from ambiguous definitions and interpretations (e.g. the well known Venn diagram of SD dimensions – [33]), the problem of the SD concept is that in economic practice the term development is a synonym of the growth of production and expansion of markets with a basic goal to increase profits. However, idea of an infinite material growth and expansion in the finite world is irrational. And we summarize results of the above analyses as follows: sustainable development is an illusion when anthropogenic pressure has brought us beyond Earth´s ecological and society´s moral limits. And human history includes records of societies which collapsed after destruction of their environment [39].

Therefore, we should admit, at least as a „plan B“, that instead of expansion we urgently need sustainable retreat [40]. Sustainable retreat (SR) should be based on limiting those human activities overshooting ecological (and social) boundaries of ecosystems, landscapes and societies, as stepping back would allow to shrink antropogenic impacts below the respective thresholds. Our theoretical backbone of the SR concept builds on a non-equilibrium thermodynamics of living systems, self-organized holarchic open system concept, mainly that of the social-ecological system (SES) – [41], as it reflects high complexity of landscapes and societies. It is important to note that SES complexity is the highest in the known universe – as it is the outcome of richness and diversity of both elements and their interactions (compare to REES [42] saying that living systems are the most complex structures of the universe). This means, we are not able to know them in full detail, but we may be able to understand the tendencies of their behaviour and development [43]. Also, the complexity of numerous interconnected positive and negative feedbacks, keeping conditions for life, causes that there is a certain time lag between human activities and full articulation of their impacts. This requires precautionary approach to abstain from activities which may in a near or distant future lead to SES system disintegration. We present a new graphical expression of sustainability:

Diagram in fig. 1 represents nesting of four basic subsystems of the SES system – ecological, social, cultural, economical and stresses that for its survival a respect to ecological and social limits (boundaries) is substantial.

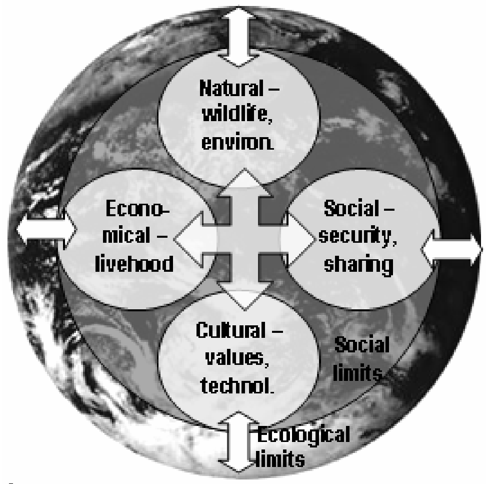

Figure 1 – Graphical expression of the concept of sustainable social-ecological system. Through ecological and social boundaries (outer rings of the cricles representing ecological and social pillars) the whole of the SES limits activities of its subsystems to safeguard its functionality and in this way defines space of sustainability. © P. Sabo, S. Cochová, 2010

A society can prosper only within landscape and planetary ecological boudaries and within social – cultural boundaries, which gave rise to civilisation. Note that in this model subsystems representing traditional pillars of sustainability are never more of equal value. Thus, no trade-off approach is possible between SES subsystems – as it is in case of the Venn diagram, which led to severe SD concept deformation.

Consequently, to live sustainably means to care for ecological integrity of ecosystems, landscapes, regions, biosphere as well as for social integrity of our societies. A disrespect to them sooner or later leads to overshoot of their ecological or social boundaries, followed by SES disintegration. Today, this integrity is under a pressure also due to a dominant mechanistic paradigm stressing individual profits and giving highest priority to macroeconomic monetary goals, regardless of the price (in this way supporting a moral relativism). Therefore, sustainable society should care also to save (and renew) good social relations between its human beings [44].

Positive signs of individual and social well-being include satisfaction of people with their personal and family life and other values of non-material standards of living. Renwick & Myerscough define the quality of life as „*the degree to which a person enjoys the important possibilities of his or her life*“ [45]. They built their concept on three pillars – being, belonging and becoming. *Being* includes physical, psychological and spiritual conditions (e.g. health, nutrition, exercise, cognition, self-esteem), *belonging* reflects connection of an individual with his home, neighbourhood and his communities (family, friends, co-workers, society) and *becoming* is an expression of creative activities that lead to self-realization and personal growth.

From theory to practice: biofuels and sustainability, new sustainability indicator. The message is clear: after peak oil without new resources of energy a retreat to simpler life would be necessary. Alternatives of renewable energy resources like biofuels may give us more time to reorganize our societies and to reform our economies. Biofuels and other renewable resources of energy may contribute to decrease of ecological footprints of industrial nations, as renewables produce lower entropy than fossil fuels [46]. On the other hand, biofuels enable to utilize only a part of the yearly regenerative biological capacity of the Earth, while fossil energy resources accumulated throughout hundreds of millions of years. It means, biofuels may replace fossil ones only to a certain percentage, if the life cycle of their production and consumption should be realized within ecological and social boundaries and should not be promoted at the expense of retreating natural and seminatural ecosystems such as primeval forests, species rich meadows, wetlands, etc. E.g. high rate of deforestation of primeval tropical forests [16] discredits clearcuts in tropics to provide more space for oil palm as a way to sustainability [47]. These clearcuts reduce area of CO_2 absorbers and cause liquidation and fragmentation of the habitats of threatened species, e.g. orangutan populations in Sumatra and Borneo [48].

Another seamy point of the biofuels production are sharply rising food prices and food shortages – mainly due to lower yields caused by long periods of droughts, but also due to production of biofuels on agricultural land and from traditional crops. Rising food prices are further widening the gap between extremely rich and hopelessly poor. There is a moral problem – it is a question whether biofuels production contributing to safeguard energy consumption for affluent living of the rich, should push out basic food production for poor [49]. Therefore, assessing impacts of biofuels on quality of life requires to explore also related social aspects. E.g. conversion of rainforests into monocultural plantations will not increase well being of aborigine communities deprived of natural resources and home. But if respecting local people and environment, biofuels may contribute to alleviation of rural poverty [50].

Sustainable retreat should be to a large extent about reduction of the current level of energy consumption in industrial world and also in semi-developed countries with rapidly growing economies (China, India, etc.). Concerning biofuels we cannot separate evaluation of their sustainability from wider assessment of ecological sustainability of a landscape where these are produced and social sustainability of societies consuming them.

This points to necessity to evaluate our progress to sustainability in a more holistic way, using variables, which would include also measures of biodiversity and ecosystems services as well as indicators based on the non-equilibrium thermodynamics applied to ecological and social systems [41, 46]. The above analysis helps us to clarify two fundamental sustainability goals:

1) life of society within ecological boundaries of the Earth: increase (or renewal) of ecological integrity of ecosystems, landscapes and ecoregions and strict adherence to respect their carrying capacity limits;

2) life of individuals and communities within social boundaries of democratic and open societies, with strict adherence to values, which in a non-violent way support social integrity of these societies.

In both cases integrity depends and is expressed by variability of SES elements (biodiversity and cultural diversity), efficacy of the solar energy dissipation as a marcoscopic measure of the SES functionality, as well as on strict respects to ecological and social carrying capacities to keep human impacts below the thresholds.

This concept implies a design of new aggregated sustainability indicator. Inspired by the Happy planet index [51] we propose more complex Happy landscape index (HLI), which considers fundamental aspects of ecological and social sustainability, including important variables implied by the thermodynamic theory:

$$HLI = \{[(S\_HDI * w_1) + (N\_QOL * w_2)] / (w_1 + w_2)\}$$
$$* \text{Ö} \; ((biocapacity / ecological\ footprint) *$$
$$\{ [(1/ LEI) * w_3] +[(1/SI) * w_4] \} / (w_3 + w_4) \}.$$

In the formula S_HDI denotes criticised but heavily used Human development index [52], N-QOL denotes an index of non-material quality of life. The second line is the square root of the rate of available biocapacity / ecological footprint of the society and denotes potential for sustainability. In the third line we consider (in the denominator) the ecological and social costs paid for society well-being in terms of changed landscape ecological integrity (LEI) and social integrity (SI). It should be noted that $0 < LEI <= 1$, $0 < SI <= 1$.

Subindex LEI is calculated as an average weighted by individual ecosystem´s area from partial EEI indexes of these ecosystems. In the EEI subindexes calculation we combine both structural and functional measures. Structural ones are based on plant diversity indexes (as crucial primary producers) and on an estimate of ecosystem disturbance, rather well indicated by the synanthropisation of vegetation. Functional measures include calculation of the efficacy of the solar energy dissipation by ecosystem (at least by each ecosystem type). Results obtained from our field research [31] confirm distinct differences of the efficacy of solar energy dissipation existing among different land cover types and among different successional stages.

Analogically, subindex SI may be calculated as a whole or as a a weighted average of the partial SI of town and village settlements. It should take into activities promotion or disruption of natural human relations, including measures of social disparity. In more detail we described the HLI index in [53].

CONCLUSIONS. Despite numerous efforts to join development and environment protection under a SD concept umbrella and despite a number of partial successes, the reality of today is deepening global cisis and overshoots of several life-support systems.

We tried to explore the cause of this in more depth using as a tool the thermodynamic theory of ecological systems. This confirms that societies are today not moving in the direction of sustainability and it is urgent to reconsider the SD concept and adjust it to reality. This leads to sustainable retreat concept, which means shrinking human activities in order to get anthropogenic impacts below currently overshooted or highly strunged ecological and social thresholds. Aspirations to increase material human affluence are legitimate, but we should also consider their price – the global SES disintegration.

Building upon non-equilibrium thermodynamics [10, 41] and on ecological economics [51] we proposed a new aggregated Happy landscape index (HLI) as an adequate tool for measurements of sustainabilty. Its design synthesises subindexes measuring human well-being, landscape and society potential for sustainability a ratio between biocapacity and ecological footprint) and changes of ecological and social integrity. We have also verified feasibility of a simpler HLI index [53].

The HLI indicator helps to clarify also renewables relation to sustainability. Their potential to contribute to reduction of entropy production by fossil fuels burning, to technological innovations, etc. [50] applies only under the strict condition of a respect to ecological and social limits of landscapes, biosphere and societies during the whole life-cycle of renewables production. New alternatives will be positive if they contribute to reversal of SES disintegration and in this way to renewal of the Earth´s capacity to support human civilization.

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РИСК ГЛОБАЛЬНОГО КОЛЛАПСА И НОВЫЕ ПОДХОДЫ К КОНЦЕПЦИИ УСТОЙЧИВОСТИ

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Несмотря на большие ожидания, связанные с внедрением концепции устойчивого развития, в реальности наблюдается разрушение систем, поддерживающих жизнь, и ускоряющееся расширение и превышение отдельных экологических границ Земли. Принимая во внимание неравновесную термодинамику живых систем, устойчивое развитие может стать реальной альтернативой и предпосылкой того, что общество должно функционировать в пределах экологических и социальных границ, должно способствовать улучшению концепции устойчивости и поиска и примененения соответствующих индикаторов оценки устойчивости развития.

Ключевые слова: устойчивость, экологические границы, экологическая и социальная целостность.

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