EMS, exergy and sustainable development in higher education

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Abstract

Physics may offer an important additional insight to the understanding of sustainable development that needs further attention particularly with regard to engineering education in sustainable development. The use of energy and other resources in the society and the consequences of this use on the natural environment as well as the conditions for sustainable development can be described and better understood by applying physical concept as exergy and exergy based methods. The concept of exergy is introduced and applied to the use of physical resources in the society and introduced as an excellent ecological indicator. Exergy as an operational concept in order to improve and optimize resource use both from a technical and economical point of view is also presented. This presentation is mainly focused on the pedagogy and didactics of teaching these topics in engineering education and in particular the advantages of doing so. This brings a new approach and insight to the engineering conditions for a sustainable development that is further elaborated in this presentation. The importance of introducing this new knowledge into present higher education in sustainable development is argued for. In short the focus is moved from meeting demands into exploiting challenges. However, difficulties and obstacles from the educational establishment are often present. These difficulties may partly relate to a problem of changing paradigm, since higher education is presently mainly engaged in the teaching and learning of engineering in unsustainable development. Pedagogical and didactic means to avoid and overcome these obstacles are also addressed.

Introduction

Sustainable development has become a central concept in politics as well as in education in most of the world and the UN has declared 2004–2014 the *Decade of Education for Sustainable Development*. The Swedish government has agreed on a National Strategy for Sustainable Development were education is stated of main importance: *Education and research in combination with skills training that reflects sustainability concerns is one key to sustainable social development in Sweden and around the world. …A sustainable development perspective must permeate all education and learning. While such an approach should convey a message, its most important objective is to provoke active participation and critical thinking about building a sustainable society* [1].
I have about thirty years of experience in this field and since 1995 I am engaged in a UNESCO group on developing an encyclopedia on sustainable development *The Encyclopedia of Life Support Systems* (EOLSS) [2]. Thus, I have developed reasons to doubt the ability to meet this goal within the present educational system. Still, we must not forget that it is exactly this system that is and has been for long time directing society into its present state of un-sustainability.
In this presentation I will focus on an alternative approach to describe and understand the conditions that are essential to sustainability. This approach is based on well established knowledge in science, however, the field of application might be new to many readers. Basic concepts, models and perspectives are exposed. Thus, I address in particular teachers and students that want to gain insight into and meet arguments on the education on sustainable development. It is my hope that this presentation will be a useful complement to traditional knowledge in the field and that it will contribute to the development of the education towards sustainable development.
The purpose is twofold to point out weaknesses of traditional often fragmented knowledge and to offer suitable knowledge for the interested reader on knowledge towards sustainable development. In

addition possible ways to meet this situation in present educational system as well as possible reactions will also be elaborated.

The ongoing depletion of nature's capital must come to an end before it is too late. Values are lost and substances are spread in the environment when nature's capital is exploited and consumed by our economies. The physical conditions in nature change and create instability. New life forms that are better fitted to these new conditions will appear, i.e. *survival of the fittest*. Some of these new organisms will not support present higher forms of life, e.g. homo sapiens. We see this as new diseases. The bird flu virus is just but one example of an ongoing creation of new organisms that will go on as long as suitable conditions are offered. Thus, present industrial society is fertilizing its own extinction. The only solution to sustainable development for humankind is to restore and preserve nature's capital. This enforces a new paradigm based on increasing the capital of nature instead of exploiting it. Present technology and social management are founded, to a large extent, on the knowledge offered by science. Yet it is precisely these structures and their impact, which we know to be unsustainable. This implies tremendous efforts from the educational system, which gradually adopts the new situation. In some areas of science this even relates to a complete change of paradigm. Science is partly the problem as well as a part of the solution for a sustainable development.

The evolution of knowledge is essential to human cultures. Every human culture carries a unique cultural paradigm—the soil for knowledge to grow and flourish. The diversity of cultures in our world is essential to the evolution of human knowledge—our creative diversity. This diversity is the wellspring of our progress and creativity.

Present focus must be on relationships; between humans and with nature. Today these relationships are characterized by greed and violence fostered by the present cultural paradigm, or arrogance and ignorance instead of friendship and compassion. This must change into a culture of peace. Peace within us, peace among us and peace with nature are essential for happiness, harmony and knowledge to flourish.

We, the people of the world, are also children of earth with a common goal to care for life itself. We were given intelligence, emotions and possibilities, but also responsibilities. With these gifts we have created a world of prosperity, but also of poverty. The world has brought us together, but also apart and away from nature. We face a future of threats and limitations, but also possibilities. These challenges demand careful and responsible actions from everyone, based on a better understanding together with moral obligations.

Nature and the physical conditions for life

Nature is the only creator and holder of life, as far as we know. From our understanding there are some fundamental physical conditions that maintain this unique capacity of nature.

In order for things to happen, i.e. motion to occur, there must be a driving force: something that can create action. A force is created by a difference in space of some kind, i.e. a contrast. This is a physical quantity such as temperature, chemical composition or pressure. Exergy is the physical concept of contrast, which quantifies its power of action [3]. A system in complete equilibrium with itself and the environment does not have any exergy, i.e. no power of action. Exergy is defined as work, i.e. ordered motion, or ability to perform work.

Energy and matter cannot be created, destroyed, produced or consumed. Energy and matter can only be converted into different forms. Locally, the contrast may increase, but this can only occur at the expense of an even greater deterioration of the contrast elsewhere. On the whole it is a question of continuous deterioration of contrast, thus, pointing out the existence and direction of time, see Fig. 1.

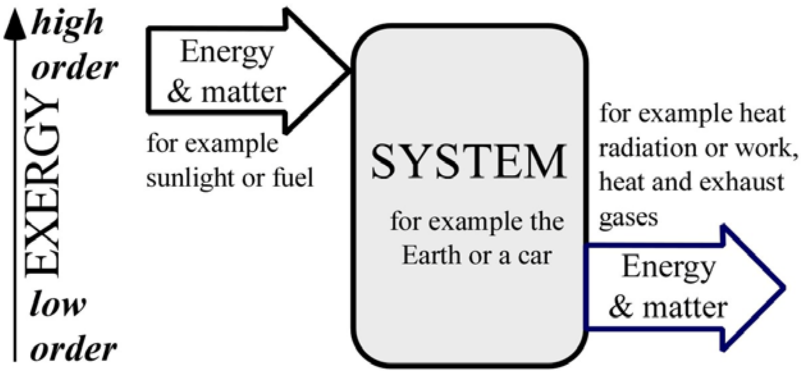

Fig. 1. The flow of energy and matter through a system.

Energy and/or matter flow through a system. The motive force of the flow of energy and/or matter through the system is the contrast or the level of order. Energy and/or matter are falling from high order, i.e. low entropy, in the inflow into low order, i.e. high entropy, in the outflow. This is also expressed as a destruction of exergy [4].

Energy and matter only serve as carriers of contrast, which is partly consumed when it flows through a system. When energy and matter flow through a system, a very small part of this may sometimes be stored in or removed from the system.

If exergy is stored in the system we may have a viable state, i.e. life may occur. Logic would suggest therefore that the existence of life and the evolution of life imply that exergy from the sun must be stored on earth.

Fig. 2. The Sun-Earth-Space system.

The source of exergy on earth is secured from the contrast between the sun and space, see Fig. 2. The exergy on earth, exists through the conversion of energy from sunlight into heat radiation, which flows from earth back into space. Due to this, all flows of energy and matter are carried forward through systems on earth's surface, and life can be created and maintained.

Life in nature relates to three fundamental processes: production, consumption, and decomposition. These maintain the circulation of matter by using the incoming solar exergy in a sustainable and evolutionary way, see Fig. 3.

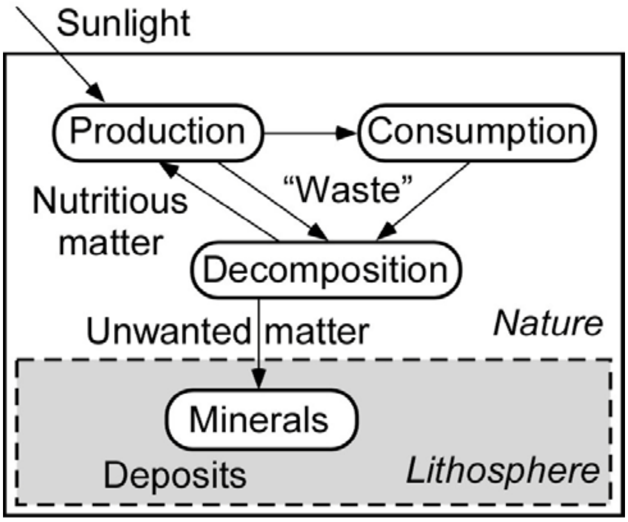

Fig. 3. The circulation of matter in nature is powered by sunlight.

Green plants, which represent the production process, convert exergy from sunlight into the exergy-rich matter of biomass, via photosynthesis. The exergy as biomass then passes through different food chains in the ecosystems. At every trophic level exergy is consumed and decomposition organisms dominate the last level in this food chain. There is no waste, however a removal of "unwanted" substances. Nature operates a unique machinery of development on earth by capturing and sealing certain substances into minerals in earth's crust. A fraction of the exergy from the sun-space contrast is stored as an increase of the exergy capital on earth. This appears as a net-flow of "unwanted" substances from the biosphere into the lithosphere as well as a redistribution of other substances in the environment, e.g. oxygen to the atmosphere. Thus, the exergy capital on earth is increasing, which is a key element in nature's process of evolution.

Society and deterioration of the physical life conditions

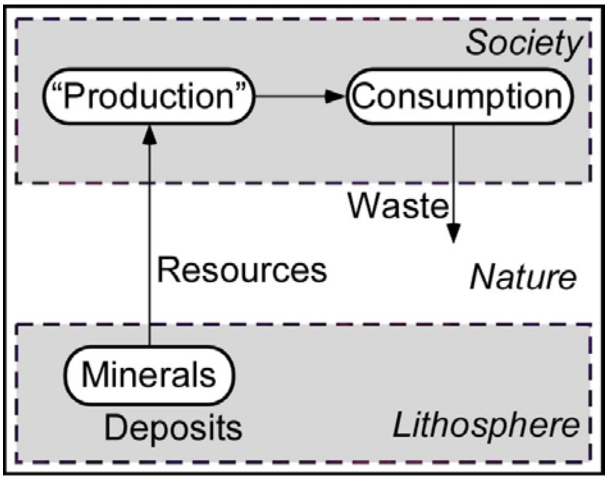

Fig. 4. Society depletes nature's capital and returns waste.

Present industrial society, is built on an unsustainable resource use, see Fig. 4. Fossil fuels and metals that originate from deposits of minerals in the lithosphere are unsealed and spread in the environment, which is exactly the opposite of what is done by nature (Fig. 3). This is obviously not sustainable, at least not for a very long time. Resource depletion and environmental destruction are two consequences of the use of deposits. In a closed system "nothing disappears and everything disperses" which state that these substances will unavoidably end up in the environment.

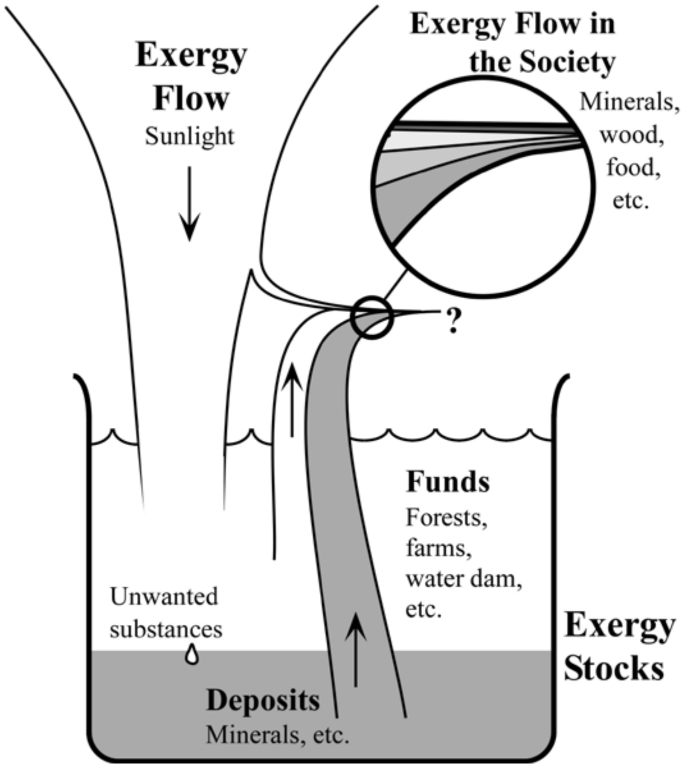

Fig. 5. Exergy flows to the society.

In Fig. 5, we see how the resource use in the society is maintained. The greater part of the exergy requirements are utilized from the terrestrial exergy stocks, i.e. funds and deposits. Only a very small part of the exergy flow from the sun is used directly. Through society we see an almost continuous exergy loss. Some exergy flows, such as flows of metals, initially increase their exergy when passing through society. However, other flows decrease their exergy all the more. An open "tank" in Fig. 5, which contains the funds and the deposits, indicates the limited amount of exergy stocks or exergy capital on earth. As long as the levels are kept stable, i.e. the output of resources does not exceed the input from the sun and the biological processes, then we have a sustainable situation. However, if the level is dropping, i.e. the exergy capital is depleting then we have an unsustainable situation and substances will also contaminate the environment. As long as these substances are under control this may not be a serious problem. Large amount of substances are accumulated in the society as constructions, e.g. buildings and machines, and, as long as these remain, their substances may not effect the environment. However, when they are allowed to decompose some of them may pose a serious threat, e.g. old nuclear, chemical, and biological arms that are not safely stored or destroyed. This also relates to harmful substances that are accumulated by a purification system, e.g. used filters and sediments from sewage treatment works, cyclone separators and scrubbers. However, human constructions and buildings will not last forever. Sooner or later they will deteriorate and their substances will end up in the environment. Thus, environmental pollution is an inevitable consequence of the use of deposits. The depletion of the resource may not be the most serious problem, but rather the emission of pollutant and unwanted substances into the environment. The concern for an eventual lack of non-renewable resources must be combined by a similar concern for the environmental impact and its consequences from the emission of these substances. Presently, only nature offers the machinery to put these substances back into the lithosphere (Fig. 3). However, the present damage may take nature millions of years to repair, and in the meantime there will be a serious impact on the living conditions for all forms of life.

Figure 6 shows the exergy flow in the society in more detail, in this case the main conversions of energy and materials in Sweden in 1994 that is more or less the same today [5]. The flows go from the resource base to the consumption sector. Thus, the diagram basically represents the resource supply sector where resources such as crops and minerals are turned into consumer goods such as food, transport and thermal comfort. The inflows are ordered according to their origins. Sunlight is thus a renewable natural flow. Besides a minor use of wind power, far less than 5 PJ, this is the only direct use of a renewable natural flow. Harvested forests, agricultural crops, and hydropower are renewable exergy flows derived from funds. Iron ore, nuclear fuels, and fossil fuels are flows from deposits, which are exhaustible and also carry with them toxic substances. The unfilled boxes represent exergy conversions, which in most cases represent a huge number of internal conversions and processes. The total inflow of resources during 1994 amounts to about 2720 PJ or 310 GJ per capita and the net output becomes 380 PJ or 40 GJ per capita. Thus, the overall efficiency of the supply sector can be estimated at less than 15%. As we can see, some sectors are extremely inefficient. Some resource conversion systems have a ridiculously poor efficiency. For nuclear fuel to space heating through short circuit heaters the net utilization becomes less than 0.025% [5].

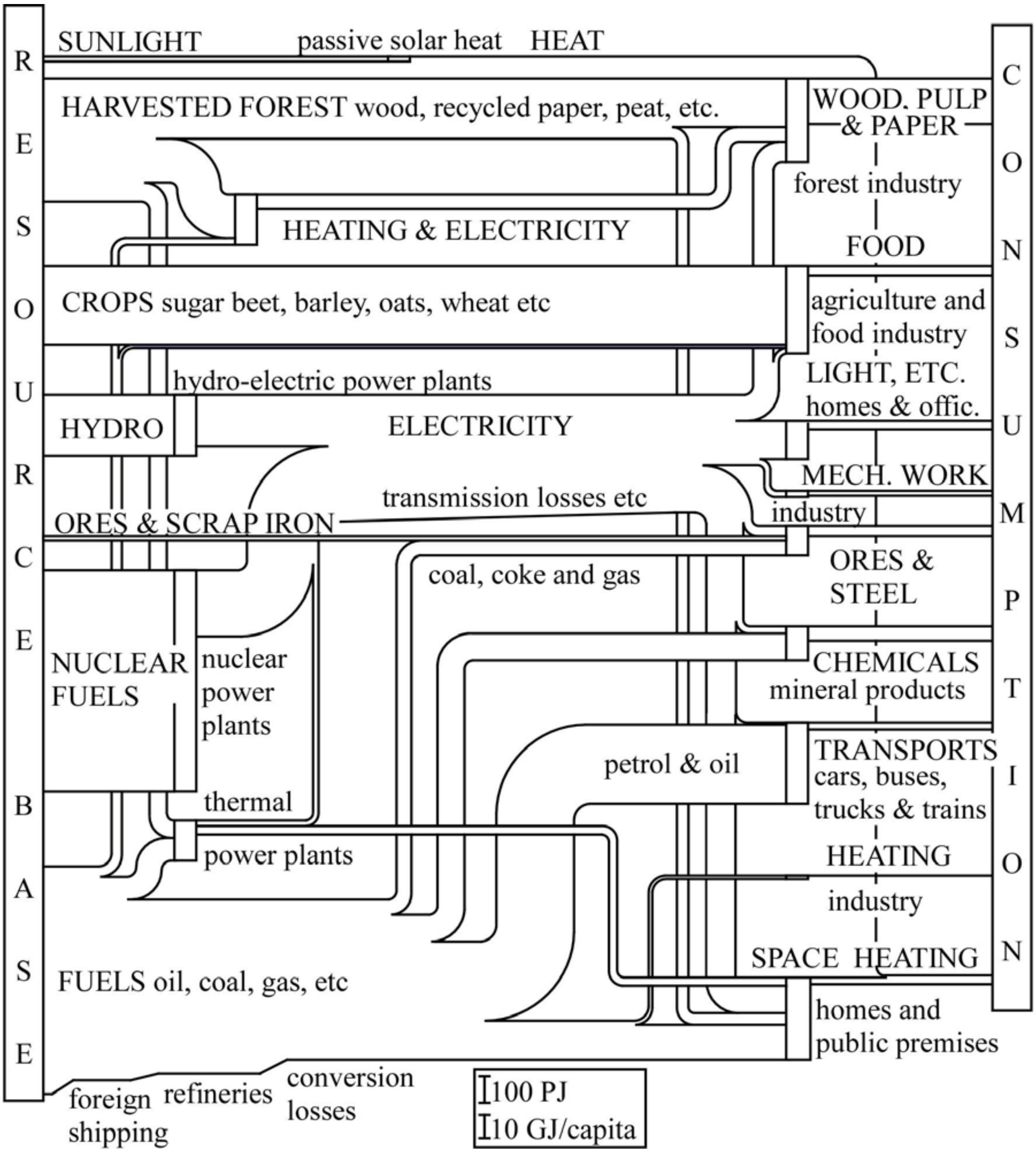

Fig. 6. Exergy use in the Swedish society in 1994.

The emission of unwanted substances from the industrial society is likely to produce diverse and unpredictable consequences in the biosphere. New microorganisms adapted to new environments will appear, see Fig. 7. Existing microorganisms, i.e. bacteria, fungi and viruses, provide the conditions on which present forms of life are founded. All forms of life are built on the existence of a specified mixture of certain microorganisms.

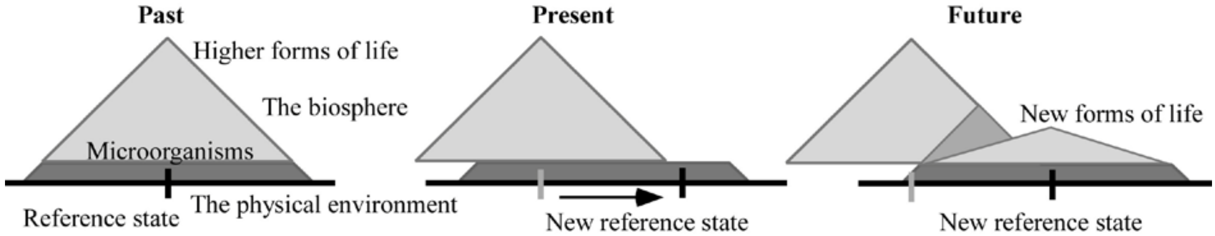

Fig. 7. "Survival of the Fittest" is a driving force in the evolution.

The incredible power of these tiny organisms must not be ignored. One single bacterium could in theory fill out the entire solar system within a few weeks if it were able to multiply without limitations. This describes the power of the living foundation of nature's life support system and the danger of interfering with this. By changing the physical conditions of the environment it becomes unfavorable for existing microorganisms as well as for higher forms of life. This may be recorded as a reduction in the number of species. However, the new physical environment that is offered will also encourage new forms of life to appear, initially by new microorganisms that are better fitted to the new conditions, e.g. bacteria that develop immunity to antibiotics. Later new insects or insects with new characteristics will appear, such as the malaria mosquito that is resistant to DDT. This is what Darwin expresses as "the survival of the fittest." Toxicity is a condition that can be reversed when transferred to different biological systems. A toxic substance is of course harmful for some organisms but at the same time it offers a new ecological niche that soon will be occupied by new organisms. This is a dangerous consequence of environmental pollution and an important perspective on the bird flu virus. The recent oil spills in the Mexican Gulf will not only kill organisms it will also feed a number of new organisms.
Thus, industrial society may nourish its own extinction by degrading the biological foundations of human existence. It would be very naive to believe that new microorganisms will only live in harmony with the present higher forms of life. The immediate signs of this are the appearance of new diseases as the bird flu virus, less resistance against existing diseases due to a weakened immune system and the increasing rate of chronic allergy.

Engineering Education in Sustainable Development

There are numerous definitions of sustainable development of which the most widely-used was coined in 1987 by the World Commission on Environment and Development in their report, *Our Common Future* [6]: "to meet the needs of the present without compromising the ability of future generations to meet their own needs." This may sound very attractive since everyone will get what they "need", now and forever. However, this does not free the rich from dealing very concretely with the problems associated with redistribution of current wealth to those who are in greater need. Still, need must be treated with global justice to remain its meaning. United Nations Development Programme Human Development Report has stated that the annual income of the poorest 47 percent of the people of the world is less than the combined assets of the richest 225 people in the world. Given this obscenely unequal distribution of wealth and income, the top fifth of the world's people consume 86 percent of all the goods and services while the bottom one-fifth must subsist on a mere 1.3 percent. Sustainable development must not become a mantra used as an excuse and justification to sustain economic growth at the expense of continued human suffering and environmental destruction. Thus, it must incorporate an explicit and well-founded notion of the globe's carrying capacity and an awareness of the consequences of exceeding this. However, since the Brundtland report was presented, resource depletion and environment destruction have only proceeded and worsen. The poor are still ignored and left out with a catastrophe. Thus, the time of lip service must be replaced with action and true change. This implies the fulfillment of moral obligations concealed for generations.

The World Commission on Environment and Development brought sustainable development to the world's attention and focused on three pillars of human well-being and sustainable development:

- economic conditions—such as wealth, employment, and technology;
- socio-political conditions—such as security and democracy; and
- environmental and resource conditions—such as the quality of our air and water and the availability of capital in the form of natural resources.

In addition to these pillars we also need to rely on certain physical conditions or a life support system for present forms of life. This could be depicted as a foundation for these pillars and for sustainable development to be reached, see Fig. 8. Without suitable physical conditions the idea of sustainable development will lack meaning no matter number or size of pillars.

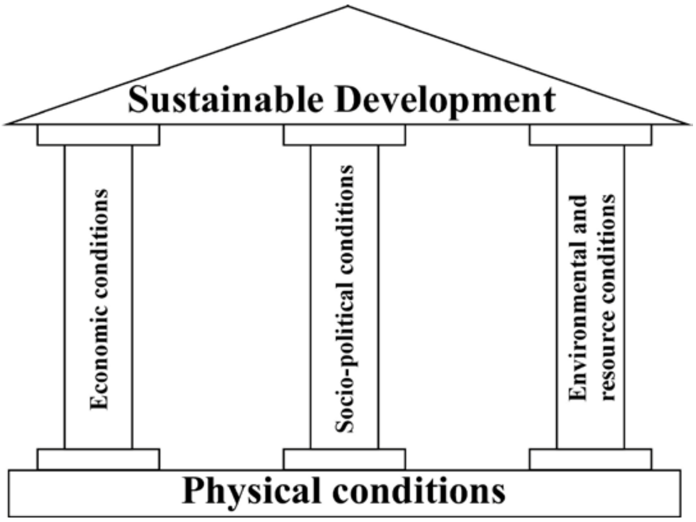

Fig. 8. Sustainable development based on suitable physical conditions.

The present unsustainable situation is due to altered physical conditions on earth that is threatening the very existence of higher forms of life including human beings. Eventually, we must look beyond present religious, economical and political structures to find the conditions for a sustainable development. This implies a revision of the present cultural structures ruling the world. In addition, from a scientific point of view it is well known that we can't solve problems by using the same kind of thinking we used when we created them. A statement related to Albert Einstein. To conclude we may say that the problem of sustainable development is not lack of resources, the problem is that we use too much and the solution is to live with less. In this regard Cuba after the collapse of the Soviet union and lack of foreign support offers interesting social results worth of study for the rest of the world in order to meet the global peak oil collapse [7].

Exergy is a suitable scientific concept in the work towards sustainable development. Exergy accounting of the use of energy and material resources provides important knowledge on how effective and balanced a society is in the matter of conserving nature's capital. This knowledge can identify areas in which technical and other improvements should be undertaken, and indicate the priorities, which should be assigned to conservation measures. Thus, exergy concept and tools are essential to the creation of a new engineering paradigm towards sustainable development.

Conclusion

From a sustainable development point of view, present industrial resource use is a dead-end technology, leading to nothing but resource depletion and environmental destruction in the long run. In the name of progress and economic development the exergy capital of the earth is depleted and substances sealed for millions of years are turned into waste in a one-way flow (Fig. 4). Instead we need to develop a vital and sustainable society, similar to what is practiced by nature.

Nature has so far generated life and awareness by means of natural evolution. Present social evolution is instead governed by increased wealth in terms of money, often indicated by Gross Domestic Production (GDP). This is when asphalt, smokestacks and color TVs replace rain forests, or when rice fields, cultivated for more than 5000 years, are converted to golf courses. This myth of progress must be questioned if we are serious in our efforts for sustainable development. At first we must find the roots to the problem. The reason for our failure is a consequence of our deep-rooted weakness for building empires. The so-called human civilizations appearing some 10,000 years ago may be characterized as the beginning of an empire builder era of humankind. This empire building era must come to an end in order to reestablish a sustainable development. Then, we must work for a change through education, true actions, practical exercises, and precaution. Finally we must secure a guidance based on morals and responsibility.

Exergy is an excellent concept to describe the use of energy and material resources in the society and in the environment. A society that consumes the exergy resources at a faster rate than they are renewed is not sustainable. From the description of the conditions of the present industrial society, we may conclude that this culture is not sustainable. One may argue about details, such as how or when, but not that a culture based on resource depletion and environmental destruction is doomed. The educational system, particularly in engineering, has a crucial role to play to meet this change towards sustainable development. This must be based on a true understanding of our physical conditions. Exergy is a concept that offers a physical description of the life support systems as well as a better understanding of the use of energy and other resources in society. Thus, exergy and descriptions based on exergy are essential for our knowledge towards sustainable development.

Time to turn is here. Time to learn and time to unlearn has come. Education must practice true democracy and morals to enrich creativity and knowledge by means of joy in learning. Culture of peace must replace cultures of empire building, violence and fear. The torch of enlightenment and wisdom carried through the human history must be shared within a spirit of friendship and peace.

Sustainable development is more and more becoming an educational problem in the society. Recent warnings from the IPCC (Intergovernmental Panel on Climate Change) all but confirm an ever increasing climate crisis due to human activities, e.g. the release of carbon dioxide into the atmosphere from the use of fossil fuels [8]. The increasing lack of understanding and action reveals a need for knowledge with more of a holistic view of the situation. Present fragmented approaches generated by the traditional educational system lack this and rather lead to further confusion. The division of knowledge into disciplines and further into even more specialized areas leads to a common lack of general knowledge and understanding of the problem among many students. This I have experienced many times during my over thirty years of teaching the subject at university and high-school levels. Instead more of a holistic approach must be adopted and applied in accordance with this presentation. The concepts presented must be incorporated into traditional knowledge and be further elaborated within the educational system. All related and relevant areas from both natural and social sciences must be treated simultaneously together with a focus on moral issues to gain understanding of the problems. Cuba's experience of meeting a severe resource situation must be further studied and learned from by the academia. My own experience of introducing these concepts into education is a strong positive feedback from most of the students and parts of the educational establishment, e.g., the UNESCO project *Encyclopedia of Life Support Systems* [2]. However, sometimes there is also a strong skepticism among some people of the academic establishment for this that also has to be dealt with. Thus, traditional boarders between different disciplines must be questioned and more of interdisciplinary studies and activities must be applied at both high school and university levels. More problem oriented approaches and a focus on moral issues are also to be encouraged. This in turn implies educational and pedagogical challenges in order to create prosperous knowledge and understanding for the development towards a sustainable or rather vital society. My hope is that this presentation will encourage and contribute to this process.

Acknowledgement

The permission to use my work for the UNESCO's Encyclopedia of Life Support Systems (www.eolss.net) for this presentation is hereby gratefully acknowledged.

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Appendix: Courses on EMS and SD at Gotland University with syllabuses

- Environmental Management Systems
- Energy & Environment
- Energy and Sustainability
- Sustainable Energy Technology
- Small Scale Energy Systems
- Exergy
- Exergy Analysis
- Exergy Economics

There is also a proposal of an online **Master of Science in Exergy and Sustainable Development**.

Syllabuses for the courses listed above follow below:

SYLLABUS FOR

Environmental Management Systems (EMS)

7.5 ECTS

CODE

NML702

APPROVAL

Approved 2008-08-28 by The Faculty Board at Gotland University, revised 2010-xx-xx. Valid as from spring term 2011.

SUBJECT AND LEVEL

Environmental and Quality Management Undergraduate level 100.

LEARNING OUTCOMES

After completing the course the students should be able to:

- Explain basic concepts on sustainable development
- Explain and reflect on the status of sustainable development worldwide
- Explain and evaluate total quality management (TQM) principals, PDCA-cycle, Profound Knowledge (E. Deming), ISO 9000, EMS principals, Life Cycle Analysis (LCA), Eco-Management and Audit Scheme (EMAS), ISO 14000, ISO 26000 and their applications
- Apply EMS tools.

CONTENTS

Unit 1. EMS Fundamentals, 3 ECTS: Basic concepts of sustainable development. Status and trends of sustainable development worldwide. TQM principles, PDCA-cycle, Profound Knowledge (E. Deming) and ISO 9000. EMS principals, Life Cycle Analysis (LCA), Eco-Management and Audit Scheme (EMAS), ISO 14000 and ISO 26000.
Unit 2. EMS Assignment, 1.5 ECTS: An EMS instruction for a specific case.
Unit 3. Individual Project Report, 3 ECTS: EMS applied to a real or realistic system.

ENTRANCE REQUIREMENTS

General entrance requirements.

TYPE OF TEACHING

Internet based with compulsory assignments, discussions and report.

EXAMINATION AND GRADES

Units 1 and 2 are examined by assignments and unit 3 by a report. Grades on units and course are Pass with distinction (VG), Pass (G), and Fail (U). The grade Pass requires Pass or higher on all units. The grade Pass with distinction requires in addition Pass with distinction on unit 2 and 3.

LITERATURE

EMAS - Eco Management and Audit Scheme, http://ec.europa.eu/environment/emas/index_en.htm

EMAS Toolkit for small organizations, http://ec.europa.eu/environment/emas/toolkit/

Environmental Management System, US Environmental Protection Agency, http://www.epa.gov/ems/

Facts of the Planet, http://www.forskning.se/theplanet/

International Institute for Sustainable Development, *Global green standards: ISO 14000 and sustainable development*, http://www.iisd.org/pdf/globlgrn.pdf

Introduction to Environmental Management Systems Training, EPA, http://www.epa.gov/osw/inforesources/ems/ems-101/

Part 1 & 2a of Guinée et al., *LCA - An operational guide to the ISO-standards*, 2001, http://www.leidenuniv.nl/cml/ssp/projects/lca2/lca2.html

The European Commission's information hub on life cycle thinking based data, tools and services http://lca.jrc.ec.europa.eu/lcainfohub/index.vm

The Story of Stuff, http://www.storyofstuff.com/

The TV-documentary *The Planet*, Sveriges television, http://svt.se/planeten

Wall, Göran. *Exergy, Ecology and Democracy – Concepts of a Vital Society or A Proposal for An Exergy Tax*, 1993 http://www.exergy.se/ftp/eed.pdf

SYLLABUS FOR

Energy and Sustainability

7.5 ECTS CREDITS

COURSE CODE

ER1002

APPROVAL

Approved 2008-01-17 by The Faculty Board at Gotland University. Revised 2010-11-23.
Valid as from Spring term 2011.

SUBJECT AND LEVEL

Energy Technology, Undergraduate level G1N.

LEARNING OUTCOMES

After completion of the course the students should be able to:

- Explain basic energy concepts, conditions and systems
- Describe and reflect on the global energy situation
- Describe and reflect on the environmental impact of energy use
- Describe the conditions on sustainable energy systems
- Reflect on sustainability in a global context

COURSE CONTENTS

Course unit 1, Energy and environment fundamentals, 2.5 ECTS Credits. Basic concepts and facts on the global resource supply and use.

Course unit 2, *Sustainable energy*, *2.5 ECTS Credits*
Conditions of sustainable development and implications on the global resource use. Future possibilities.

Course unit 3, *Individual Project Report, 2.5 ECTS Credits*
Analysis of energy systems from a sustainability perspective.

ENTRANCE REQUIREMENTS

General entrance requirements.

TYPE OF TEACHING

The course is given as in English Internet based university course.

EXAMINATION AND GRADES

Course units 1 and 2 are examined by exercises. Course unit 3 is examined by a written report. Course grades on all units are Pass with distinction (VG), Pass (G), or Fail (U).
The grade Pass requires the grade Pass or higher on all course units. The grade Pass with distinction also requires a minimum of two course units, including course unit 3, with the grade Pass with distinction.

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Valda delar

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Göran Wall, 2010, "On Exergy and Sustainable Development in Environmental Engineering", *The Open Env. Eng. J.*, vol. 3 pp. 21-32 http://bentham.org/open/toenviej.

In addition about 250 pages from other sources.

SYLLABUS FOR

Exergy

7.5 ECTS

CODE

TER713

APPROVAL

Approved 2008-08-28 by The Faculty Board at Gotland University, revised 2010-xx-xx. Valid as from spring term 2011.

SUBJECT AND LEVEL

Energy Engineering advanced level A1N.

LEARNING OUTCOMES

After completion the student should be able to:

- Apply the exergy concept to real systems.
- Describe sustainable development from an exergy point of view.

CONTENT

Unit 1. Exergy Fundamentals, 2.5 ECTS: Fundamental energy and exergy concepts, Thermostatics and thermodynamics, Cyclic processes, Heat transfer and Chemical processes.

Unit 2. Exergy Calculations, 2 ECTS: Exergy studies of different systems and process.

Unit 3. Individual Project Report, 3 ECTS: Exergy studies of real or realistic systems.

ENTRANCE REQUIREMENTS

At least 60 ECTS in engineering and/or natural science, or equivalent and good ability in mathematics and English or at least Mathematics C and English B at Swedish high school level.

TYPE OF TEACHING

Internet based with compulsory assignments, discussions and report.

EXAMINATION AND GRADES

Units 1 and 2 are examined by assignments and unit 3 by a report. Grades on units and course are Pass with distinction (VG), Pass (G), and Fail (U). The grade Pass requires Pass or higher on all units. The grade Pass with distinction requires in addition Pass with distinction on unit 2 and 3.

LITERATURE

Gong, M. & Wall, G. *On Exergy and Sustainable Development, Part II: Indicators and Methods* (2001) pp. 17, http://www.exergy.se/ftp/gw2exij.pdf

Wall, G. *Exergetics* (2009) pp. 151, http://www.exergy.se/ftp/exergetics.pdf.

Wall, G. & Gong, M. *On Exergy and Sustainable Development, Part I: Conditions and Concepts* (2001) pp. 18, http://www.exergy.se/ftp/wg1exij.pdf

SYLLABUS FOR

Exergy Analysis

7.5 ECTS

CODE
TER719

APPROVAL
Approved 2009-06-24 by The Faculty Board at Gotland University, revised 2010-xx-xx. Valid as from spring term 2011.

SUBJECT AND LEVEL
Energy engineering advanced level A1F.

LEARNING OUTCOMES
After completion the student should be able to:

- Analyze real energy and material conversion systems from an exergy point of view.
- Reflect on the sustainable use of physical resources.

CONTENT
Unit 1. Exergy Analysis Fundamentals, 2.5 ECTS: Exergy concepts and methods, Life Cycle Analysis, Energy Systems, Life Cycle Exergy Analysis (LCEA), sustainable resource use.
Unit 2. Exergy Analysis Applications, 2 ECTS: Exergy analyses of different systems and process.
Unit 3. Individual Project Report, 3 ECTS: Exergy analyses of real or realistic systems.

ENTRANCE REQUIREMENTS
At least Exergy 7.5 ECTS or equivalent.

TYPE OF TEACHING
Internet based with compulsory assignments, discussions and report.

EXAMINATION AND GRADES
Units 1 and 2 are examined by assignments and unit 3 by a report. Grades on units and course are Pass with distinction (VG), Pass (G), and Fail (U). The grade Pass requires Pass or higher on all units. The grade Pass with distinction requires in addition Pass with distinction on unit 2 and 3.

LITERATURE
Cutler J. Cleveland, *Net Energy From the Extraction of Oil and Gas in the United States* 17 p. http://www.bu.edu/cees/people/faculty/cutler/articles/Net_%20Energy_US_Oil_gas.pdf
Gong, M. and G. Wall, *On Exergy and Sustainable Development, Part II: Indicators and Methods* (2001) 17 p. http://www.exergy.se/ftp/gw2exij.pdf.
Muilerman and Blonk, *Towards a sustainable use of natural resources* (2001) 18 p. http://ec.europa.eu/environment/enveco/waste/pdf/muilerman.pdf.
The Eco-indicator 99 A damage oriented method for Life Cycle Impact Assessment (2000) 144 p. http://www.pre.nl/download/EI99_methodology_v3.pdf.
The Exergoecological Portal, http://www.exergoecology.com/excalc/index_html/new_calc_exergy.
Zvolinschi, Anita. *On exergy analysis and entropy production minimisation in industrial ecology*, (2006) 216 p. PhD Theses, NTNU, http://ntnu.diva-portal.org/smash/record.jsf?pid=diva2:122541.
Wall, G. and M. Gong, *On Exergy and Sustainable Development, Part I: Conditions and Concepts* (2001) 18 p. http://www.exergy.se/ftp/wg1exij.pdf.
Wall, G., *Exergy Flows in Industrial Processes*, Energy, Vol. 13, No. 2, pp. 197-208 (1988) http://www.exergy.se/ftp/paper3.pdf, http://www.exergy.se/ftp/paper3fig52.pdf, and http://www.exergy.se/ftp/paper3fig62.pdf.
Wall, G., *Exergetics* (2009) 151 p. http://www.exergy.se/ftp/exergetics.pdf.

SYLLABUS FOR

Exergy Economics

7.5 ECTS

CODE

TER721

DECISION

Approved 2009-09-16 by The Faculty Board at Gotland University, revised 2010-xx-xx. Valid as from spring term 2011.

SUBJECT AND LEVEL

Energy engineering advanced level A1F.

LEARNING OUTCOMES

After completion the student should be able to:

- Analyse and optimize real systems with respect to exergy and total cost.
- Evaluate results as above with respect to sustainable development.

CONTENT

Unit 1. Exergy Economics Fundamentals, 2.5 ECTS: Cost-benefit analysis including taxes and subsidies. Efficiencies of ideal and real processes. Optimization methods and their applications. Fundamental processes as heat exchanger and combustion.

Unit 2. Exergy Economics Applications, 2 ECTS: Thermoeconomics and cost functions for important unitary processes, Exergy Economic Accounting (EEA) and Exergy Economic Optimization (EEO). Design optimization techniques, e.g., Pinch Technology and "Energy Utility Diagram". Sensitivity analysis.

Unit 3. Individual Project Report, 3 ECTS: Exergy economic analyses of real or realistic systems.

ENTRANCE REQUIREMENTS

Exergy Analysis 7.5 ECTS or equivalent.

TYPE OF TEACHING

Internet based with compulsory assignments, discussions and report.

EXAMINATION AND GRADES

Units 1 and 2 are examined by assignments and unit 3 by a report. Grades on units and course are Pass with distinction (VG), Pass (G), and Fail (U). The grade Pass requires Pass or higher on all units. The grade Pass with distinction requires in addition Pass with distinction on unit 2 and 3.

LITERATURE

Boyd, S. and Vandenberghe, L. *Convex Optimization* (2008) 730 p. Cambridge University Press, http://www.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf.

El-Sayed, Yehia M. "Thermodynamics and Thermoeconomics", Int. J. Applied Thermodynamics, Vol. 2 (No.1), pp.5-18, March-1999. http://www.icatweb.org/vol2/2.1/5-el-sayed.pdf

El-Sayed, Yehia M. *The Thermoeconomics of Energy Conversions* 2003 276 p. http://www.ebookee.com/The-Thermoeconomics-of-Energy-Conversions_193404.html

Gong, M. and Wall, G. *On Exergy and Sustainable Development, Part II: Indicators and Methods* (2001) 17 p. http://www.exergy.se/ftp/gw2exij.pdf.

Quantities, Units and Symbols in Physical Chemistry (1993) 165 p. Blackwell Science, http://www.iupac.org/publications/books/gbook/green_book_2ed.pdf.

The Exergoecological Portal, http://www.exergoecology.com.

Wall, G. *Thermoeconomic optimization of a heat pump system*, Energy 11, 957-967 (1986) and International Journal of Refrigeration14, 336-340 (1991) http://www.exergy.se/ftp/paper4a.pdf and http://www.exergy.se/ftp/paper4b.pdf.

Wall, G. and Gong, M. *Exergy Analysis versus Pinch Technology* (1996), presented at ECOS'96, Efficiency, Costs, Optimization, Simulation and Environmental Aspects of Energy Systems, June 25-27, 1996, Stockholm, Sweden, publ. P. Alvfors et al Eds., ISBN 91-7170-664-X, pp. 451-455 http://www.exergy.se/ftp/eavpt.pdf.

Wall, G. and Gong, M. *On Exergy and Sustainable Development, Part I: Conditions and Concepts* (2001) 18 p. http://www.exergy.se/ftp/wg1exij.pdf.

Wall, G. *Exergetics* (2009) 151 p. http://www.exergy.se/ftp/exergetics.pdf.

SYLLABUS FOR

Small Scale Energy Systems

7.5 ECTS CREDITS

SMÅSKALIGA ENERGISYSTEM
7,5 HÖGSKOLEPOÄNG

COURSE CODE

TER718

APPROVAL

Approved 2009-06-24 by The Faculty Board at Gotland University. Revised 2010-05-26.
Valid as from autumn term 2010.

SUBJECT AND LEVEL

Energy Technology, Undergraduate level, G1F.

LEARNING OUTCOMES

After completing the course the students should be able to:

- Describe sustainable energy systems and their characteristics
- Describe resource efficient use including storage systems
- Design small scale sustainable energy systems with regard to function, applicability, economy, environmental and social impact

COURSE CONTENTS

Course unit 1. Renewable energy resources 2 ECTS Credits
Different sustainable energy systems for small scale applications. Energy conversion and storage engineering.

Course unit 2. *Applications 2 ECTS Credits*
Applications of small scale sustainable energy systems. Off grid supply systems. Different conditions in different parts of the world.

Course unit 3. *System design, 3.5 ECTS Credits*
Design of an off grid sustainable energy supply system.

ENTRANCE REQUIREMENTS

Specific entrance requirements: Wind Power - Basics 7.5 ECTS Credits
or Energy and Sustainability 7.5 ECTS Credits or equivalent knowledge.

TYPE OF TEACHING

The course is given as an Internet based university course in English. Exercises and assignments are submitted to the e-classroom on the Internet and participants are given personal feedback by their tutors. A forum for discussion is also available.

EXAMINATION AND GRADES

Course units 1 and 2 are examined by exercises. Course unit 3 is examined by a written report. Course grades on all units are Pass with distinction (VG), Pass (G), or Fail (U).

The grade Pass requires the grade Pass or higher on all course units. The grade Pass with distinction requires a minimum of two course units, including course unit 3, with the grade Pass with distinction.

LITERATURE

Selected parts of the literature below.

David JC MacKay, *Sustainable Energy — without the hot air*, 2009, http://www.withouthotair.com (382 s.)

Energy Assessment Energy and the Challange of Sustainability, United Nations Development Programme, 2000, http://www.undp.org/ (508 s.)

Energy and Environment for Sustainable Development, http://www.undp.org.ph/?link=11

Global Village Energy Partnership, http://www.gvepinternational.org/

Lester R. Brown, *Plan B 4.0 – Mobilizing to Save Civilization*, Earth Policy Institute, 2010, http://www.earthpolicy.org/images/uploads/book_files/pb4book.pdf (369 s.)

Renewable Energy in Swaziland, http://www.ecs.co.sz/reaswa/REASWA_Renewable_Energy_in_Swaziland_Booklet.pdfReports from United Nations Development Programme, http://www.undp.org/energy/

Rural Energy Development Programme (REDP), http://www.redp.org.np/phase3/

Sustainable Energy Solutions for Rural Areas, http://www.biog.as/sustainer.pdf

Additional material of about 250 pages.

SYLLABUS

Sustainable Energy Technology

7.5 ECTS CREDITS

COURSE CODE
TER720

APPROVAL
Approved 2009-12-17 by The Faculty Board at Gotland University. Revised 2010-xx-xx.
Valid as from Spring term 2011

SUBJECT AND LEVEL
Energy Technology, Undergraduate level 200

LEARNING OUTCOMES
After completion of the course the students should be able to:

- Analyse and evaluate present energy systems with regard to sustainability
- Define and explain the conditions on Sustainable Energy Systems (SES)
- Propose economizing and efficiency improvements of energy systems
- Formulate strategies to make energy systems more sustainable

COURSE CONTENTS
Course unit 1, Sustainable Energy Systems Theory, 2 ECTS Credits
Energy utilization and efficiency. Concepts and methods. Energy economizing. Sustainable development conditions.

Course unit 2, Sustainable Energy Systems Analysis, 2 ECTS Credits
Analysis of real systems with respect to SES.

Course unit 3, Sustainable Energy Systems Project, 3.5 ECTS Credits
Project report on applying SES criteria to a real or realistic system.

ENTRANCE REQUIREMENTS
Specific entrance requirements: Energy and Sustainability, 7.5 ECTS Credits or equivalent.

TYPE OF TEACHING
The course is given as an Internet based university course in English. Exercises and assignments are submitted to the e-classroom on the Internet and participants get personal feedback from their tutors. A forum for discussion is also available.

EXAMINATION AND GRADES
Course units 1 and 2 are examined by exercises. Course unit 3 is examined by a written report. Course grades on all units are Pass with distinction (VG), Pass (G), or Fail (U). The grade Pass requires the grade Pass or higher on all course units. The grade Pass with distinction requires a minimum of two course units, including course unit 3, with the grade Pass with distinction.

LITERATURE
David JC MacKay, *Sustainable Energy — without the hot air*, 2009, http://www.withouthotair.com (382 p.)

Energy Assessment Energy and the Challange of Sustainability, United Nations Development Programme, 2000, http://www.undp.org/ (508 p.)

Göran Wall, 1977, *Exergy a Useful Concept within Resource Accounting*, Report No. 77-42, (8 p.), Institute of Theoretical Physics, Göteborg. http://www.exergy.se/ftp/ex77c.pdf.

Göran Wall, 1988, "Exergy Flows in Industrial Processes", *ENERGY*, Vol. 13, No. 2, pp. 197-208 http://www.exergy.se/ftp/exindproc.pdf.

Göran Wall & Mei Gong, 2001, "On Exergy and Sustainable Development, Part I: Conditions and Concepts" *Exergy An International Journal*, Vol. 1, No. 3, pp. 128-145, http://www.exergy.se/ftp/wg1exij.pdf.

Mei Gong & Göran Wall, 2001, "On Exergy and Sustainable Development, Part II: Methods, Applications and Suggestions", *Exergy An International Journal*, Vol. 1, No. 4, pp. 217-233, http://www.exergy.se/ftp/gw2exij.pdf.

Göran Wall, 2002, "Conditions and Tools in the Design of Energy Conversion and Management Systems of a Sustainable Society"*Energy Conversion and Management*, vol. 43, no. 9-12, pp. 1235-1248 http://www.exergy.se/ftp/ctdecmsss.pdf.

Göran Wall, 2010, "On Exergy and Sustainable Development in Environmental Engineering", *The Open Env. Eng. J.*, vol. 3 pp. 21-32 http://bentham.org/open/toenviej.

In addition about 250 pages from other sources.