Quality, Sustainability and Indicators of Energy Systems

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This book is devoted to the quality and sustainability assessment of complex energy, water and environment systems. Resource, economic, environmental, technology and social indicators are used for evaluation of the respective systems. The book will include following chapters:

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FOREWORD

Quality is a fundamental property of life support complex systems. Typical examples of complex systems can be seen in the ecosystem. Its complexity overwhelmingly shows that our life with different epistemological and ontological changes is under critical constraints which require better understanding of the processes leading to the sustainable development of the life on our planet. With the diversification of the effort within the scientific community to focus attention to the multicriteria evaluation of our life, the changes in historical processes in economic, technological, social, cultural and environmental domains will lead to the better acceptability of scientific understanding and research results.

Sustainability revolves around a new notion describing our duty to preserve commodities given to us by nature. As Christian, Jewish and Islamic religions have introduced in their fundamental obligation of man to preserve natural capital on our planet, it is only recently in geological time that we have recognized the importance of our duties. In this respect, many government and non-government organizations have expressed the need to introduce actions to comply with preservation of the natural capital on our planet. It was noticed that there are limits to the use of natural capital, which are requiring immediate actions before it will be too late. A number of studies presented by the scientific community are signaling to the community at large that future research in natural and human sciences has to pay attention to the future development of the complex systems. In this respect, the sustainability has become not only a scientific field but also a movement with specific aims.

Indicators are parameters to measure properties of the systems. They can be signs or numbers, which are defined to reflect specific properties of the system. Collecting information and its processing will convert them in data. So, data represent agglomerated information, which are partially or finally processed. In the case of sustainability, we need to verify those indicators which reflect properties of complex systems. In order to cope with the complexity of sustainability-related issues for different systems, indicators have to reflect the wholeness of the system as well as the interaction of its subsystems. The effective indicator has to meet characteristics reflecting a problem and criteria to be considered. Its purpose is to show how well a system is working. Indicators are strongly dependent on the type of system they monitor. It is known that any number, semantic expression or mathematical sign is information. Also, positive or negative signs of the variable are also information. In order to use the data for the assessment of the respective system, it is necessary to convert them into the indicator. So, the indicator represents a measuring parameter for the comparison between different states or structures of the system. Also, we can evaluate different structures of the systems by the indicator.

Energy system is a complex system with a respective structure and can be defined by different boundaries depending on the problem. In simple analysis with only function of energy system designed to convert energy resources in the final energy form, the interaction of energy system is defined by its thermodynamic efficiency. Adding respective complexity to the energy system, we can follow interaction of energy system and environment. In this respect, a good example is a pollution problem, which is defined as the emission of energy and material species resulting from the conversion process. With further increase in complexity of the energy system and establishing respective communication through the boundary, there are other entities fluxing between the system and its surroundings. Since every energy system has a social function in our life, its link may also be established between the energy system and its surroundings, taking into consideration social interaction between the system and environment. In our analysis, we have assumed that the energy system is a complex system which may interact with its surroundings by utilizing resources, exchanging conversion system products, utilizing economic benefits from conversion processes and absorbing the social consequences of conversion process. Each of the interaction fluxes is a result of the very complex interaction between elements of the energy system within the system and with surroundings. In our analysis we will use synthesized parameters of the system in form defined in classical analyses of energy systems.

This book is a collection of the materials authors have published in the last several years and comprises two parts. The first parts, including Chapters 1 through 4, are devoted to the new method for energy system evaluation based on the multicriteria assessment. The second part comprises application of multicriteria method on different energy systems. Attention is focused on clean air technologies, new and renewable energy systems, hydrogen systems, biomass systems, solar systems and multicriteria evaluation water efficiency, water desalination systems and evaluation of heat sink design for computer systems.

Authors want to express high appreciation to colleagues who participated in the development of the multicriteria method development. In particular we would like to express our thanks to Prof. Nikolai Hovanov (St. Petersburg University, Petersburg) for his support in development of the mathematical tool used in the multicriteria assessment. In dealing with a number of different energy systems we had a great help from our colleagues who are experts in different fields, namely: Prof. Mohammad Darwish (University of Kuwait, Kuwait) in water desalination; Prof. Avram Bar-Cohen (University of Minnesota, Minneapolis) in heat sink design; Prof. Petros Pilavachi (Aristotle University of Thessaloniki, Thessaloniki) in natural gas turbine plants; Dr. Ayfer Veziroglu, (International Association for Hydrogen Energy, Coral Gables, USA) in hydrogen system evaluation; Dr. Predrag Radovanovic (VINCA Institute of Nuclear Sciences, Belgrade) in energy engineering.

It was our great pleasure to work with Begell House, Inc. publishing staff. In particular we would like to express our high appreciation to Ms. Vicky Lipowski and Ms. Erica Salcuni for the excellent work in editing this volume.

It is an obligation to our families to express recognition for their contribution in preparation of this book by their constant appreciation of our efforts in writing this book.

November, 2007

CHAPTER 1

1 INTRODUCTION

Quality is defined as the characteristic that constitutes the basic nature of a thing or is one of its distinguishing features. In this definition, “thing” can be expressed in a broad variety of meanings. It can be a product, agglomerated products, a simple system, a complicated system, and a complex system.

The quality of products is defined by their properties, including geometrical, material, financial, adaptability, lifetime, and other attributes. It is obvious that each of the properties is defined in a specific scale with respective numerical graduation.

The agglomerated products are characterized by the quality of individual products but also by characteristics of a set qualifying the differences among elements of the set. These characteristics are usually described by the statistical interpretation of the respective set.

If products are agglomerated in the simple system with a specific functionality, the quality of this system can be described by a physical law. A typical example of a simple system is the Carnot cycle (Fig. 1.1), which is an agglomeration of the specific elements to perform conversion of heat in mechanical work. The quality of this system is defined by the Carnot efficiency of the system. A system is *simple* if it can be adequately captured using a single perspective description and by a

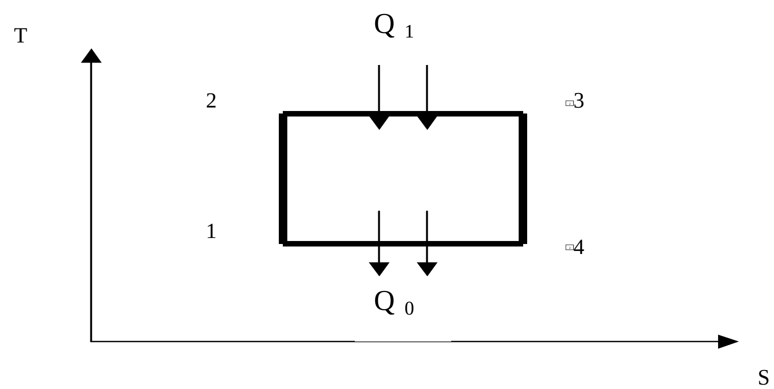

Figure 1.1 The Carnot cycle—A Simple System

standard (e.g., analytical) model providing a satisfactory description through routine operations (e.g., ideal gases, mechanical motion, and the like).

An essential feature of a complicated energy system (see Fig. 1.2) is functional agglomeration of the elements in order to perform high-efficiency energy conversion. The mutual relationship of elements is described by the model including the function of the elements and performance of the system. A typical example of this type of system is a cogeneration energy system, which is designed to obtain high efficiency of energy conversion with heat and electricity production including environmental interaction with its surroundings [2]. Quality measurement of such a complicated system is usually defined by an optimization procedure using a respective optimization function leading to a set of the system's parameters. A system is *complicated* when it cannot satisfactorily be captured through the application of a standard model, although it is possible to improve the description or the solution through approximations, computations, or simulations. However, a complicated system can be characterized by using a single perspective (e.g., a system of many billiard balls in movement, cellular automata, or the pattern of communications in a large switchboard). We consider, as the basic criterion to separate the *complex* from the complicated, the need to use two more additional perspectives, or descriptions, in order to characterize the system.

In the past, technology has normally taken the road of increasing efficiency combined with increasing complexity, a higher economy of scale, and thus a concentration of risks. The quality of a complex system has to be defined with multi-criteria indicators agglomerated in the group with the same scale. These groups

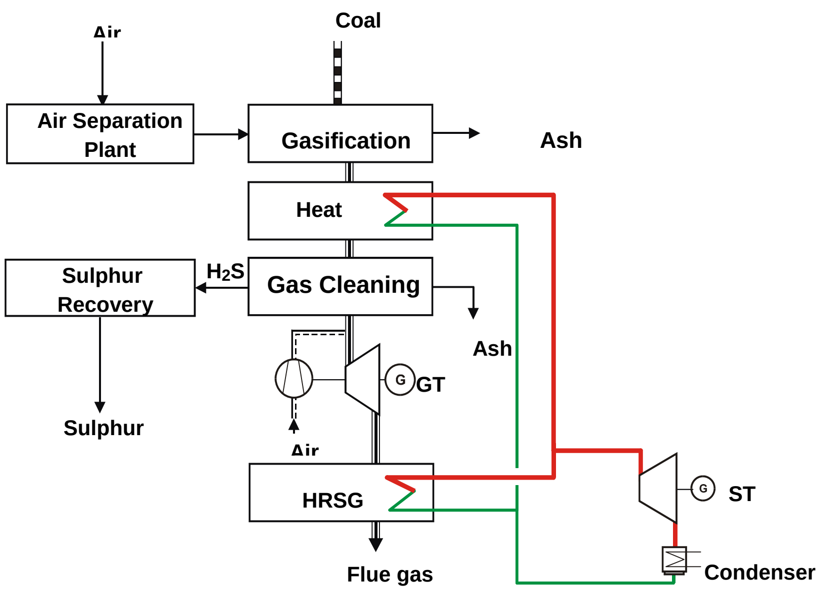

Figure 1.2 Complicated Energy Systems

will represent different features of the complex system including resources, economy, environment, and social characteristics of the system.

Developing the concept of sustainability has moved from nature conservation to a minimization of the effects on the health of the population, an increase in social welfare, and recently to the quest for higher resource efficiency. In moving to the issue of resource productivity, there is a discontinuity in innovation that has been overlooked by most policy makers. But real innovation is chaotic. In addition, the real challenge still lies ahead, to move from a sustainable economy to a sustainable society. Technological and societal evolution has led to high *anonymous* systems vulnerability. The manufacturing industry is responsible for the quality of its products, not their usefulness or disposal. Sustainable production implies a *cradle-to-cradle* approach used by legislators and economic actors, instead of a disposal optimization for wastes. The precautionary principle will increasingly play a role in this context.

Agenda 21, adapted by the Rio Conference 1992 [3], was applied with specific tasks to the scientific community to make political policy strategy for the twenty-first century. It has been ten years since this document has been addressed on the number of scientific, engineering, and political meetings without a significant breakthrough in understanding and promoting actions that will lead the development of our society to meet the essential concept of sustainability. It is of paramount importance for us to develop a notion based on modern scientific knowledge that will help us to understand the basic concept of sustainability. In this respect, sustainable science is defined as a challenging attempt to focus the attention of the scientific community at large, to dwell into a basic knowledge in different fields and emulate them by the respective complexity to reveal a new understanding of the future of our planet.

1.1 GLOBALIZATION

In the complexity definition of the sustainability concept there are three clusters of indicators, which are in use to describe the state of global system. There are: resource, environment, and social cluster of indicators. There are three processes that are immanent to the development of our planet, namely, globalization, democratization, and decentralization (Fig. 1.3).

Recently, it has become evident that economic forces are driving forces that are transferring capital and material resources, and manpower through the global space without obstacles posed by the local, state, and regional boundaries. The process of economic reform is named globalization. The contemporary revival of interest in the field of international political economy has coincided with the appropriately unprecedented restructuring of the world economy to be labeled as globalization. The forces of changes associated with globalization have been felt through state societies to such an extent that it has become the focus for a large amount of research undertaken across the social sciences. The comprehension of globalization will require substantial contribution in order to become firmly recognized as a field of interest for social science. With globalization representing a critical junction for the development of political economy, a combination of inter-

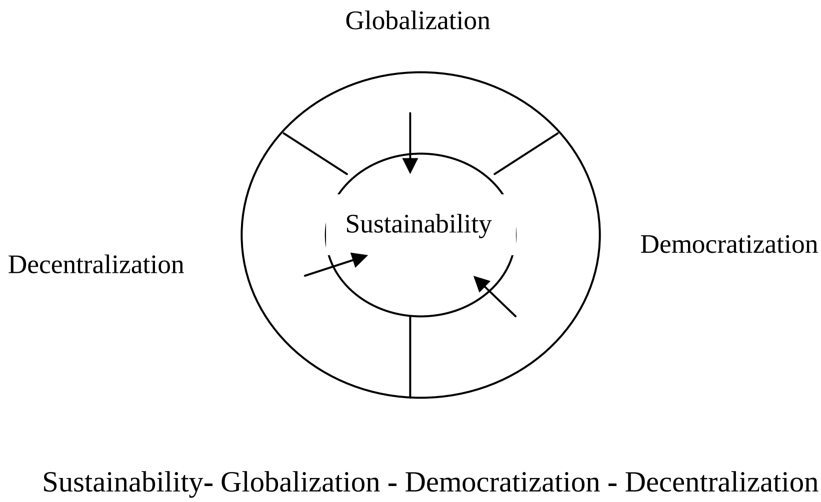

Figure 1.3 Schematic Presentation of Interaction

disciplinary relations and literal economies do not seen capable of providing the foundation necessary for the consolidation of the field. The interdisciplinary insight in global economy with respective structure needs knowledge of the system and respective parameters to describe the state of the system. The intensity of globalization is assessed by the quantities that are used as the indicators reflecting the state of the system under consideration. This implies that the process of economic reform will be measured by the respective indicators' change in the time scale. The globalization process is taking place in the system; so that the system parameters are supposed to be the measuring parameters of the intensity of processes in the system. In this respect the intensive parameters of the system are to be used in the determination of the state of the system. Thermodynamically speaking, the intensive parameters are specific quantities of the respective extensive parameters. In this case, it could be understood as specific capital, specific material, specific resources, and specific manpower. In the engineering practice, in order to become operational indicators have to be measured as the state parameters of the system. Since we are interested in measuring the change of the state of the system, it is necessary to introduce as the indicators of the globalization process the respective changes of the intensive parameters of the system. So, as the indicators for the globalization process the following parameters can be adopted: rate of change of specific capital, rate of change of specific material, rate of change of specific resources, and rate of change of specific manpower.

In the case of sustainability assessment of the globalization process, we will be interested in monitoring the change of indicators that are the result of the eventual change of the system structure. In case of the assessment of the specific system, as state, region, urban region it will be needed to determine respective indicators expressed in the form of the aggregated function of the individual indicators. This level of aggregation will require a respective model of the system and its aggregation function. The sustainability assessment of the globalization process will imply a complex systems approach with the aggregation function including all respective indicators reflecting effects of the individual processes in the observed system.

1.2 DEMOCRATIZATION

Democracy is the principles of equity of right, opportunity, and treatment [5]. The process leading to the establishment of social organization based on the democracy principles is democratization. So, the democratization process can be defined within the different boundaries including local, regional, and global environment. The intensity of the democratization process is dependent on the number of attributes reflecting ethnic, religious, cultural, and educational environment. For every socially structured system the respective indicators reflecting different aspects of the democratization process can define the intensity of the democratization process. Individual parameters defining specific characteristics of democratization can be used to measure the intensity of the democratization process. Among those are: equity of right, job opportunity, and treatment. Each of the parameters can be defined as the specific value of the internal parameter of the system under consideration. As the internal parameters of the respective parameters the indicators of the democratization process can be defined as: specific number of citizens' participation in the voting system, specific number of job opportunities in the system, and many others. Since the democratization process is also defined by the respective indicators cluster, it is of interest to make the assessment with reference to effect of the social parameters defined by the democratization on the observed system. Again, we have to form a respective aggregation function that will describe the state of the system. In this respect the sustainability assessment can be used as the decision-making paradigm for the system assessment.

1.3 DECENTRALIZATION

It has been proved that the large energy and water systems are economically better justified then small systems. In the past, a driving force in the decision-making process under economic constraints has been to build the large systems. With a new wave of miniaturization, it has become evident that in the complex system assessment the priority may be given to the smaller system [6]. In this respect the recently developed governing system is seeing more support for the local government. The same can be applied to the development of energy, water, and environment systems. Smaller cogeneration units have become an attractive solution in many areas, leading to better economic, environmental, and social values in the use of available resources. The modern micro gas turbine with respective cogeneration unit has proved to be justified by the complex assessment method. The goal of the network system is therefore to investigate options and pathways for an accelerated transition toward sustainable energy technologies and systems. In this respect, the appropriate selection of the criteria and respective indicators with corresponding progress have opened a new venture in the development of our society. In this respect, it is our need to look ahead in order to see if we can forecast our future in the near-term and long-term scales. This is a reason that a number of scholars have devoted substantial attention to the future of our society. It is obvious that there are needs to dwell into the complexity of this issue in order to be able to understand the processes that are going to affect our future.

It should be noticed that through the history of human society the changes in the pattern of the social structures have been linked to the cyclic development of the human structure. These changes are result of the critical states that have been achieved at the specific period of time reflecting the need for the addition of a new complexity in human society. In this respect the industrial revolution has introduced commodities to our society, which by itself contributes to the increase of the complexity. Nearing the end of the industrial revolution, it has become evident that complexity indicators such as population, economics, material resources, social structure, and religious devotion have reached a state that requires our special attention.

There have been a number of scholars who have emphasized individual aspects of the present state of our civilization. In particular the attention was focused to the indicators related to the material resources and environment. In our history there have been many attempts to emphasize different aspects of the use of the material resources. Some of those are drawn from the ethic principles founded in the religious faith that that we owe to be in compliance with the human role in the divine. Warning has been issued as the sign that we are reaching certain limits after which the irreversible changes are expected. The first and second energy crises have shown the vulnerability of the present state of our society. Recent claims have been made that the concentration of CO_2 is reaching a limit that may trigger irreversible changes in the environment with catastrophic consequences for the life on our planet.

Special attention is devoted to the most recent development of the concept of sustainability science. A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. Such an understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors. With a view toward promoting research necessary to achieve such advances, it was proposed an initial set of core questions for sustainability science.

Numbers of scientific meetings have been devoted to the different aspects of the resources limits. It has been unambiguously proved that there are limits. The accuracy of the assessment method may only affect the time scale of our prediction. This fact has become a driving force for the promotion of programs to mobilize human, economic, and technological entities to take actions needed to prevent the adverse effect to our civilization.

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