Preface

This may be the first time for you to see the word “exergy”, or you may have heard or seen it before. Those of you who know exergy as one of the names of a variety of thermodynamic concepts might have regarded it to be as difficult to understand or not useful, unless you have been familiar with exergy-efficiency calculation for chemical process engineering or power plant engineering.

It was in the early 1980s when I first heard the word “exergy” whose meaning was far beyond my reach of understanding; while it sounded attractive to me though I could not make any reasoning.

Professor Isao Oshida (1914–1987), who was one of the Japanese scientists famous for his pioneering work on solar-energy utilization, told me one day, almost 30 years ago, the following:

> The word ‘energy’, which we use in conversations related to so-called ‘energy’ issues, is not exactly the same as the concept of “energy” itself, which had been formulated by the mid-nineteenth century and is now well-defined as one of the most important scientific concepts. It should be the concept of “exergy” to discuss the ‘energy’ issues. We need to take a careful review on the so-called ‘energy’ issues from the standpoint of “exergy”.

I can recall that moment I heard this from him very clearly even now. Those days the focus of my research was to have a better understanding of the built environment with respect to lighting, heating, and cooling, and thereby to develop better systems with less fossil fuel use. My research then was being made from the energetic viewpoint alone and it was not clear to me whether the concept of exergy is applicable to the field of built environmental science and engineering. I was not brave enough to jump immediately into thermodynamics even in relation to built environment at that time, although what professor Oshida mentioned attracted me very much.

The name of exergy was given in early 1950s by Z. Rant (1909–1971), a Slovenian engineering professor who did research on thermodynamic application to chemical industry processes, but the conceptual formulation of exergy was not necessarily given first in the mid-twentieth century. A trial of mathematical

formulation was already made in a period of a few decades around the turn of nineteenth to twentieth century by some thermodynamic scientists such as J. Jouguet (1871–1943), G. Gouy (1854–1926), A. Stodola (1859–1942) et al. As we seek the origin of the exergy concept, we can go back to the scientific paper written in the 1820s by S. Carnot (1796–1832), a French scientist, who took the foremost key role to find the science of thermodynamics.

Since the name of exergy was given by Z. Rant, exergy research and its application have been made in particular as an efficiency index of various industrial processes involving the production of electric power, thermal power, and chemically synthetic materials.

Before I started to be involved in exergy research focusing on the built environment, the concept of exergy looked as if it belonged to the field of fundamental thermophysical science or to the applied engineering sciences, such as thermomechanical and chemical engineering. In other words, the concept of exergy appeared to have nothing to do with built environmental science. Looking back on those days, it was quite natural that I could not easily decide whether I should bring in the concept of exergy into the field of built-environmental science since my level of understanding the exergy concept was poor.

One other reason that I was afraid of jumping into exergy research was that I felt as follows: *We researched intensively and extensively the concept of exergy and we would have understood clearly what it is. But, unfortunately, the most important conclusion was that the concept of exergy is not useful at all in the field of built-environmental science. This would make me depressed very much and if it was so, my research would have been a process to prove my stupidity or how low my capability to do research is. Moreover, I must be criticized due to the fact that I brought young graduate students belonging to my laboratory onto the wrong track away from the right track.*

As I mentioned above, the concept of exergy sounded attractive from the very first moment I heard about it. These days, I recognize that my curiosity about the exergy concept must have transferred in a good way to some of the students in my classes or lectures I have had since early 1990s. I often told my students that there is an interesting concept called "exergy" waiting for further research.

The following fellow researchers in particular, who once belonged to my laboratory at TCU as graduate students for their respective projects aiming at Ph.D. dissertations, let me notice various research problems to be tackled with and also they contributed to the advancement of exergy research from their respective interests. They are, in the order of when they were at my laboratory:

Dr. Ryoji Nishikawa (Associate professor, Akita University);

Dr. Itaru Takahashi (Associate professor, Tokai University);

Dr. Masaya Saito (Associate professor, Sapporo City University);

Dr. Hideo Asada (Research engineer, Arch-Tech Consulting, Co., Ltd.);

Dr. Koichi Isawa (Assistant professor, Toyota National College of Technology);

Dr. Toshiya Iwamatsu (Senior research engineer, Central Research Inst. of Electric Power Industry);

Dr. Marcel Schweiker (Assistant professor, Karlsruhe Inst. of Technology);

Dr. Hirotsugu Yamada (Research engineer, Sumitomo Forestry, Co., Ltd.);
Ms. Kayo Tokunaga (Researcher, Shukuya laboratory, TCU).

To which portions of this book they have contributed is acknowledged before the references in the respective chapters. If there are any mistakes or incorrect descriptions in this book, they are of course all owing to my carelessness, but not theirs.

Having been encouraged by them, I have been able to pursue our research program aimed at finding sound solutions for so-called 'energy' and environmental issues associated with the built environment together with a better understanding of the exergy concept itself.

This book describes what has become clear to us in the course of our exergy research over the last 20 years; it tries to deliver the essence of the exergy concept as precisely, and as easily as possible to the readers who are not yet familiar with thermodynamics and building thermal sciences.

This book consists of two parts. The first part, from Chaps. 1 to 3, describes what has been found through our exergy research over the last 20 years since the early 1990s with a brief introduction to the concept of exergy as a starter. The second part, from Chaps. 4 to 5, describes our own development of thermodynamic theory from the very basic level of the first and second laws together with the definition of temperature to an advanced level of exergy theory for the application to built environmental science that we have so far reached.

If a glance at the whole of this book gives you an impression that it will be hard to read, I would like to invite you to read at least the first chapter. If you have then recognized it interesting while still not easy, I am quite sure that you would enjoy going through the second and third chapters and thereby share the essence of our findings through the exergy research.

I think that it is all right for you to read these chapters with a feeling of some uncertainty about the exergy concept. You could then go on to the following chapters, Chaps. 4 and 5, in which the theoretical formulations are given. Going will hopefully guide you to understand the exergy concept, other thermodynamic concepts, and also what the built environment is together with how it should be controlled to be in harmony with our immediate nature.

In fact, there is quite a lot beyond what I learned through our exergy research associated with built environment. For instance, the science in the twentieth century was advanced very much while at the same time divided into many fields of science, most of which seem to be standing alone and not coming together with other fields. Built environmental science is no exception. Many researchers tend to stick to their own confined discipline and to show little interest in other disciplines than their own. I have to confess that I myself was one of those, especially before getting involved in our exergy research.

In the years to come in the twenty-first century, I believe it is necessary for each of us as researchers or practitioners to make a connection between disciplines, as it is like having two eyes for us to be able to have three-dimensional sight. Such effort enables us to have a better knowledge on the built environment to be created based upon a deeper understanding of our nature. This is what I have recognized

due to my experience in our research efforts trying to forge the link between built-environmental science and thermodynamics.

Through our exergy research, I have also become curious about the learning process of human beings; in other words, how human brains grow from a state of "will-not-understand" to that of "understood". In our process of researching and discussing the concept of exergy aimed at its application to built environment, I came to know that almost everybody asks the same type of questions depending on their level of understanding. It seems universal across cultures.

How the human brain works in terms of learning is probably one of the hardest scientific and philosophical questions to answer, but what I can say now is that there seems some universal pathway for human beings to learn. Having this kind of on-the-job experience in mind I tried to write the whole of this book-the last two chapters in particular—in a manner that we guide the readers through such seemingly universal questions by answering them step by step with the learning process in mind. I believe that it would also be nice to reveal how we have come to the core of exergy concept from the state of "not-understand" to our present state of "understood".

The application of exergetic theory, I believe, awaits various other fields in addition to the built environmental science. If some of the readers stimulated by reading this book jump into the exergy research as we did, it would be to our pleasure.

This book may look to be aimed at graduate students and researchers, Chaps. 4 and 5 in particular, but I hope that the first three chapters would be welcome by engineers and architects in practice. If those involved in environmental design practice or in the development of sound technology for sustainable societies could enrich their understanding, through reading at least the first three chapters, it would also be to my pleasure. I believe that sustainable environmental design or sustainable technology development can be realized by those having an understanding of what we discuss in this book.

Yokohama, Japan, May 2012 Masanori Shukuya

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