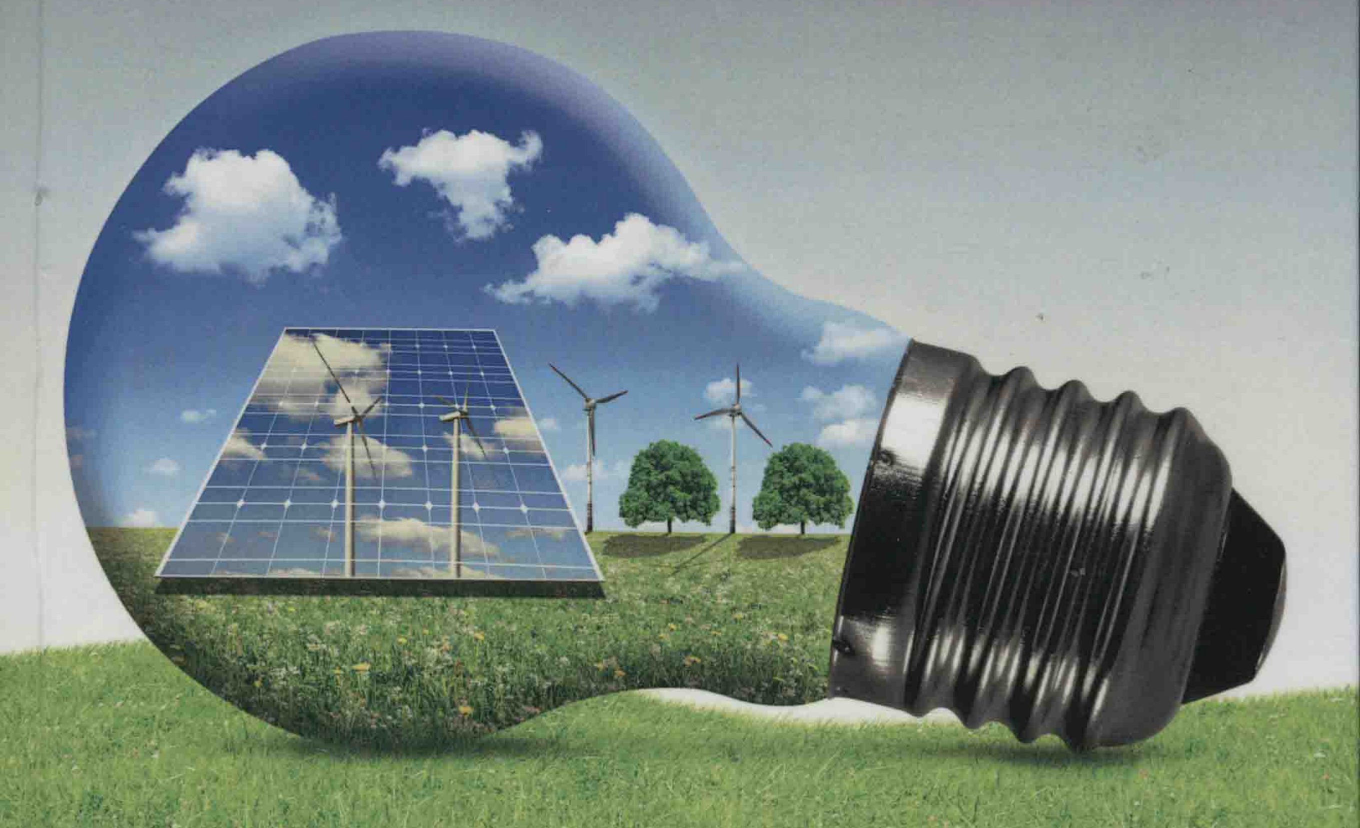
Introduction to Energy Technologies for Efficient Power Generation



Alexander V. Dimitrov

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Introduction to Energy Technologies for Efficient Power Generation

Nature seeks and finds transition from less to more probable states

Ludwig Botzmann

The book was written based on a series of lectures as part of an academic course on "Heat technics and Power engineering." It is structured as to cover the horarium of 45 hours of a teaching plan and it comprises six modules

- Theoretical basis of energy conversions and thermodynamics
- Thermal motors (thermal engines)
- Thermal-power energy technologies
- Regeneration and recuperation of waste energy
- Energy transfer and accumulation
- Energy and indoor conditions

Alexander V. Dimitrov

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Author

Alexander V. Dimitrov is a professional lecturer with 35 years of experience at four different universities. In addition to universities in Bulgaria, Dr. Dimitrov has lectured and studied at leading scientific laboratories and institutes in other countries, including the Institute of Mass and Heat exchange "Likijov," Byelorussian Academy of Sciences, Minsk; Lawrence Berkeley National Laboratory, Environmental Energy Technology Division, Indoor Environment Department; UNLV College of Engineering, Center for Energy Research, Stanford University, California, Mechanical Department.

Professor Dimitrov has conducted systematic research in energy efficiency, computer simulations of energy consumption in buildings, the distribution of air flow in an occupied space, modeling of heat transfer in the building envelope, and leaks in the ducts of HVAC (heating, ventilation, and air conditioning) systems.

Professor Dimitrov has defended two scientific degrees: Doctor of Philosophy (PhD) (in 1980) and Doctor of Science (DSc) (in 2012). With significant audit experience in the energy systems of buildings and their subsystems, he has developed an original method for evaluating the performance of the building envelope and energy labeling of buildings. He also has experience in the assessment of energy transfer through the building envelope and ducts of HVAC systems. Professor Dimitrov's methodology has been applied in several projects with great success. He has developed a mathematical model for assessment of the environmental sustainability of buildings, named BG_LEED. He earned his professor degree in "engineering installations in the buildings" with the dissertation "The building energy systems in the conditions of environmental sustainability" at the European Polytechnical University in 2012. Subsequently, he has authored more than 100 scientific articles and 9 books, including 4 in English.

Abbreviations

AC	Air conditioning
ACS	Automatic control system
BACS&M	Building Automatic control system and monitoring
CS	Cold source
CW	Construction works
DDC	Direct digital control
DTEG	Direct thermo electrical technology
EC	Energy center
ED	Energy department
EE	Energy efficiency
FC	Fuel cell
FES	Fossil energy sources
GBA	Gross building area
GDP	Gross domestic product
HDT	Hydro dynamical technology
HI	Heating installation
HP/HV	High pressure/voltage
HS	Heat source
ICE	Internal combustion engine
InDET	Indirect thermo electrical technology
LDC	Lower dead center
LH/LV	Low pressure/voltage
LtDC	Left dead center
MHG	Magneto hydrodynamical generator
NPS	Nuclear power station
NSTA	Nuclear steam turbine assembly
PhEA	Phase exchange accumulation
PSHS	Pumped-storage hydropower station
PV	Photovoltaic cell
RDC	Right dead center
RES	Renewable energy sources
TDC	Top dead center
TDP	Thermodynamical process
TDS	Thermodynamical system
TPS	Thermal power station
TWC	Typical weather conditions

Introduction

The utilization of energy is the key to understanding modern civilization. The field of energy science began its successful development after the 18th century, at which time a majority of important scientific discoveries related to energy occurred. It was discovered that energy could cause global ecological catastrophes and even the destruction of the human race, if not properly utilized.

The book *Introduction to Energy Technologies for Efficient Power Generation* reveals the technologies for the production, storage, and transfer of energy related to the energy and building industries, and transportation. It is intended to be a reference tool for current and future leaders, managers, and specialists in these areas, which will help them with the effective and environmentally friendly utilization of energy resources.

Together with the classic energy technologies for energy conversion, discovered by W. Rankine, G. Brayton, R. Stirling, and N. Otto, the book describes some of the technologies less known by the general public, such as

- The osmotic technology of D. Bernoulli
- The thermoelectric technology of T. Seebeck
- The photovoltaic technology of A. Becquerel/W. Shottky
- The technology of the controlled oxidation of fuels of C. Schonbein/W. Grove in the fuel cells
- The vortex technologies of G. Ranque and Merkulov/Y. Potamov
- The cold nuclear fusion technology of A. Rossi

The book also covers the technologies of regeneration and recuperation of waste industrial energy, as well as technologies for the generation of energy from renewable resources, such as solar, wind, and geothermal.

The book describes the contemporary concepts for thermal and electric energy transfer through solid bodies at the microscopic thermodynamical level. Also discussed are the methods for effective control of energy fluxes in technical equipment and appliances, including building envelopes.

Finally, also discussed is the work organization as well as desired competencies of energy managers for industrial, public, commercial, and residential buildings. The book focuses on the role of organizational leaders for the maintenance and proper usage of the systems responsible for the internal comfort of the environment, that is, temperature, lighting, and clean air in the serviced buildings. Also included is a description of the systems for thermal comfort and their elements.

Chapter 1: Theoretical Foundations of Energy Conversions and Thermodynamics

Chapter 1 treats basic notions and laws of energy conversion—the principles of thermodynamics. For instance, "ideal gas" and Einstein "ideal solid" are presented as working bodies where energy conversion takes place. Laws of energy conversions and their directions are formulated in detail, and the types of thermodynamic process are also explained. The basic requirements to power machines (engines, generators/converters, etc.) are set forth and machine classification from a functional point of view is given. Energy efficiency is also discussed employing the ideal thermal engine of Nicolas Leonard Sadi Carnot as an energy standard.

In addition, the first part clarifies the characteristics of various types of real energy conversion. For instance, details concerning a working body where phase conversions take place are outlined, or compressibility of working fluids and interatomic forces, Ranque vortex effects, and Joule–Thompson inverse temperatures and their applications in the heat generators of Potapov and Hirsch are accounted for.

The next chapters of the book discuss some basic types of energy conversion referred to as thermal-energy technologies, such as

- Heat-mechanical energy conversion
- Heat-electric energy conversion
- Regeneration and recuperation of thermal energy

Chapter 2: Conversion of Thermal Energy into Mechanical Work (Thermal Engines)

The development of thermal engines and steam and gas turbines, in particular, yielded significant change in power technologies, unleashing mass exploitation of electricity in households, industry, and transport.

Initially, the so called externally fired thermal engines were designed. These were the steam engines of Denis Pippin, Thomas Newcomen, and James Watt, the engines of Stirling, the steam turbine of Parsons, and the gas turbine of John Barber. They were known for the heat generation devices (combustion chambers and boilers) that were physically separated from the operating mechanisms (power cylinders and mechano-kinematical chains). Moreover, accessible and cheap heat sources were used—wood biomass and its derivatives (firewood was mostly used till the end of the 19th century), charcoal and coal (their use started at the beginning of the 15th century).

An improvement of thermal engines gathered momentum in the mid-19th century and consisted of efficiency increase and the minimization of the overall dimensions of engines. The innovative idea was to combine the combustion chamber and the power cylinder into one solid machine unit. The "internal combustion engine" materialized this new concept. Otto and Langen were the first to practically realize the idea in 1858. Later, Atkinson (1882), Rudolf Diesel (1890), and Miller (1947) modified and improved it, while a modern version of the engine is that of Felix Wankel (1951). The Brayton engine and its modification in the gas-turbine and gas-compressor engines are also described. Thermomechanical technology employing external heat sources are presented by the Stirling engine.

Each thermal technology discussed herein will be illustrated by specific physical schemes and devices.

Chapter 3: Thermoelectric and Co-Generation Technologies

This chapter discusses some energy-conversion technologies where heat is directly converted into electricity or is a previously created product by energy conversions. We shall analyze the following technologies:

- Conversion of solar radiation into electricity (the so called "internal ionization")
- Seebeck technology applied in thermos-couples (the so called "thermoelectric current")
- Schonbein/Grove technology with oxidation control
- Rankine cycle technology
- Brayton cycle technology

The advantages of the co-generation processes and devices operating within the Brayton clockwise cycle and their adaptively to household energetics are underlined. The employment of thermoelectric and cogeneration technologies in the design of vehicle hybrid gears is also discussed.

Each thermal technology discussed herein will be illustrated by specific physical schemes and devices.

Chapter 4: Energy Rehabilitation: Regeneration and Recuperation

In this chapter, the technologies for energy rehabilitation are classified in two groups as shown in

- Regeneration technologies, where the energy potential of the working fluid is used directly or increased by keeping the energy form—generally by increasing the temperature or pressure of the authentic energy-charged medium
- Recuperation technologies, where the available energy potential of the working fluid is used to change the energy form (for instance, "heat or mechanical motion to electricity" at the expense of a more complete use of the residual enthalpy)

Some new modern technologies of electric power generation are disclosed—osmotic technology, hydro dynamical technologies, solar concentrators, and that of low-temperature plasma, magnetic hydrodynamic generators.

Each thermal technology discussed herein will be illustrated by specific physical schemes and devices.

Chapter 5: Energy Transfer and Storage

Technologies of energy transfer and storage are also addressed. Four different microscopic level models are based on hypothetical mechanisms that were developed during the 1940s. These are

Kaganov's model or a two-step mechanism of interaction between phonons and electrons, Geier's model and Kumhasi's model, A. Majumdar's model and model of lagging temperature gradient.

In the bodies under the influence of the environment (external energy fluxes or electromagnetic or gravitational fields) directed movement of micro particles occurs

- Type fermions (electrons and ions), or
- Quasi particles (bosons type: photons or phonons by means of internal ionization or polarization of the atomic structures)

The movement of these particles in the transmission medium is hampered by the body's structural components (atomic lattices or molecular entities). This process is accompanied by transfer of an amount of movement from the quasi particles (bosons) flow toward the lattice, whose internal energy (respectively temperature) is changed, proportional to the flux value. Thus, the change in the body's temperature is caused by the directed movement of quasi particles, delaying (lagging) in time relative to the passage of their flow. The four models of heat transfer in solids contribute to the understanding of the physical character of transfer.

We shall discuss in what follows their features and practical methods of their regulation by the introduction or avoidance of thermal resistance, such as volume or Fourier resistance, capacitive resistance (due to storage), fluid dynamic resistance (due to convection), and reflection resistance (due to radiation).

When the working body of a thermodynamic system is solid, the transferred energy is assessed by the total energy transfer law, giving the relation between the specific energy flux **h** and the gradient of free energy potential in the solid body.

Chapter 6: Energy and in Door Enviroment

Specific environmentally friendly energy conversions in inhabited areas of buildings and passenger vehicles are outlined at the end of the chapter.

A favorable and comfortable indoor environment can be attained employing two architectural-engineering technologies which complement each other:

- Passive technologies
- Active technologies

The first type exploits the functional properties of the envelope of an object (building or vehicle) to filter environmental impacts such as solar radiation, wind, humidity, and aerosol emissions. Once designed and laid, the envelope operates as an insulation saving energy needed to provide a friendly indoor environment.

The second type uses energy generated in central or local power stations. That energy is needed by the devices to change the parameters of the indoor environment, offering thermal, illumination, and air comfort.

The systems of thermal comfort regulation are divided into three basic groups with respect to the mechanisms providing comfort in the inhabited area:

- *Convective systems.* The necessary local conditions for thermal comfort in the inhabited area are created by convective heat transfer and change of the air temperature T_a
- *Radiative systems.* Comfort via those systems is attained mainly by change of the radiant temperature T_R of the heaters located around the inhabited area. Air temperature T_a is generally kept constant
- *Convective–radiative systems.* Temperature T_a as well as temperature T_R vary in the conditioned area

Considering the working fluid in the distribution network, the systems are subdivided into: air-to-air; water-to-air; steam-to-air; electricity-to-air; and gas-to-air. With respect to heat transfer, they are classified as

- Systems using natural convection
- Systems with forced convection

Systems providing thermal comfort (air conditioning or heating) reflect the specificity of the objects involved. Hence, engineering offers a number of systems which differ from each other with respect to the internal arrangement of heat distribution. There are four basic methods of air cleaning (purification) and control of the contaminants in rooms and passenger compartments (applied independently or combined with each other): source elimination or modification; use of outside air to remove contaminants (space ventilation); local ventilation; and air cleaning. Each thermal and air cleaning technology discussed herein will be illustrated by specific physical schemes and devices.

The last part of the Chapter 6 discusses the work organization as well as desired competencies of energy managers for industrial, public, commercial, and residential buildings. The book focuses on the role of organizational leaders for the maintenance and proper usage of systems responsible for the internal comfort of the environment, i.e., temperature, lighting, and clean air in the serviced buildings.