

IEEE Press Series on Systems Science and Engineering

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Energy Conservation in Residential, Commercial, and Industrial Facilities



edited by
Hossam A. Gabbar


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**ENERGY
CONSERVATION
IN RESIDENTIAL,
COMMERCIAL, AND
INDUSTRIAL FACILITIES**

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ENERGY CONSERVATION IN RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL FACILITIES

Edited by
HOSSAM A. GABBAR

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Library of Congress Cataloging-in-Publication Data is available.

ISBN: 978-1-119-42206-8

Cover design: Wiley

Cover image: © WangAnQi/iStockphoto

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

I dedicate this book to my wife Naila Gaber for her great support,
and to my son John Gaber and daughter Sophia Gaber for
inspiring and motivating me to complete the book.

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PREFACE

Energy consumption in infrastructures represents almost one-third of total energy demand. As energy is linked to greenhouse gas emissions, which is linked to climate change and global warming, it is important to provide intelligent systems to support both energy conservation and energy supply in infrastructure systems.

This book shows business model and engineering design framework for practical implementation of energy conservation in infrastructures such as buildings, hotels, public facilities, industrial facilities, transportation, and water/energy supply infrastructures. Key performance indicators are modeled and used to evaluate energy conservation strategies and energy supply scenarios as part of the design and operation of energy systems in infrastructures. The proposed system approach shows effective management of building energy knowledge, which supports the simulation, evaluation, and optimization of several building energy conservation scenarios. Case studies are used to illustrate the proposed energy conservation framework, practices, methods, engineering designs, control, and technologies.

This book will offer the following new concepts:

- Infrastructure energy modeling
- Building envelope modeling
- Energy conservations methods
- Energy semantic networks (ESN) superstructures
- Energy conservation strategies and performance measures
- Examples in HVAC, lighting, appliances, storage, and machines

- Energy conservation optimization techniques
- Risk-based life cycle assessment
- Control strategies and systems for energy conservation
- Advanced energy audit systems

This book is structured into four parts:

Part I Energy Infrastructure Systems

Part II Energy Systems

Part III Energy Conservation Strategies

Part IV Resiliency, Protection, Control, and Optimization Systems

This book will help technology providers, infrastructure support industries, construction companies, municipalities, and regulatory institutions to study and manage energy conservation in infrastructures that include residential buildings, industrial facilities, transportation, and city infrastructures.

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ACKNOWLEDGMENTS

The editor would like to thank all contributors to this book, and the research team at the Smart Energy Systems Lab (SESL) at UOIT for their full dedication and quality research. Also, the editor would like to thank IEEE SMC for providing the chance to publish this work. We acknowledge UOIT for their continuous support to the research work at SESL.

PART I

ENERGY INFRASTRUCTURE SYSTEMS

CHAPTER 1

ENERGY IN INFRASTRUCTURES

HOSSAM A. GABBAR^{1,2}

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1.1 INFRASTRUCTURE SYSTEMS

As measured in 2015, around 1.2 billion people, constituting 17% of the global population, do not have electricity, and 2.7 billion people, constituting 38% of the global population, have risks on their health due to the reliance on the traditional use of biomass for cooking [1].

In order to discuss energy systems and conservation strategies in infrastructures, it is essential to analyze the infrastructure physical systems and their types, classifications, and energy requirements. It is possible to find a suitable definition of infrastructures as the fundamental facilities and systems that serve a region, area, community, city, or country, including the support facilities such as utilities, services, and transportation that are necessary for the economic development and perform all necessary functions. There are number of ways to classify infrastructures, such as size, criticality, use, occupancy, location, and surroundings. Infrastructures can support residential functions, commercial and public functions, transportation functions (including land, sea, air), and industrial functions. Infrastructures can be viewed as system of systems; for example, infrastructures include communications and cyber security, computational/technological, waste management, emergency and disaster management, defense and military, and other supporting infrastructures. The better we understand infrastructures, the better we design and operate energy systems in these infrastructures. Infrastructure modeling should support design and operational activities, with appropriate and comprehensive performance measures to evaluate design and operation features

Energy Conservation in Residential, Commercial, and Industrial Facilities, First Edition.

Edited by Hossam A. Gabbar.

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and alternatives. Requirement analysis of infrastructures should include energy demand, risk management, performance, and sustainability requirements.

1.1.1 Infrastructure Classifications

Energy use in infrastructures can be controlled and optimized based on the nature of loads and energy systems implemented in these infrastructures. For proper planning, design, and operation of energy systems to support these infrastructures, it is important to analyze the classifications of infrastructures. Figure 1.1 shows hierarchical classification of infrastructures based on nature, type, use, function, and energy requirements. There are interrelations among these infrastructures, for example, water infrastructures are linked to residential, industrial, and commercial. Similarly, energy and waste are linked to all other infrastructures.

In order to understand energy consumption in different regions, power consumption in Ontario has been selected, as presented in Figure 1.2, where it shows the consumption in residential, commercial, industrial, electric vehicle, transit, and others. Power consumption in residential is very close to that consumed in commercial, while industrial is the third dominating sector for power consumption.

1.1.2 Infrastructure Systems

Infrastructure system includes technical and technological infrastructures to support all functions and the management of life cycle activities in infrastructures including flow and control of information across all elements of the infrastructure systems. Modeling of processes of infrastructure systems includes players, roles,

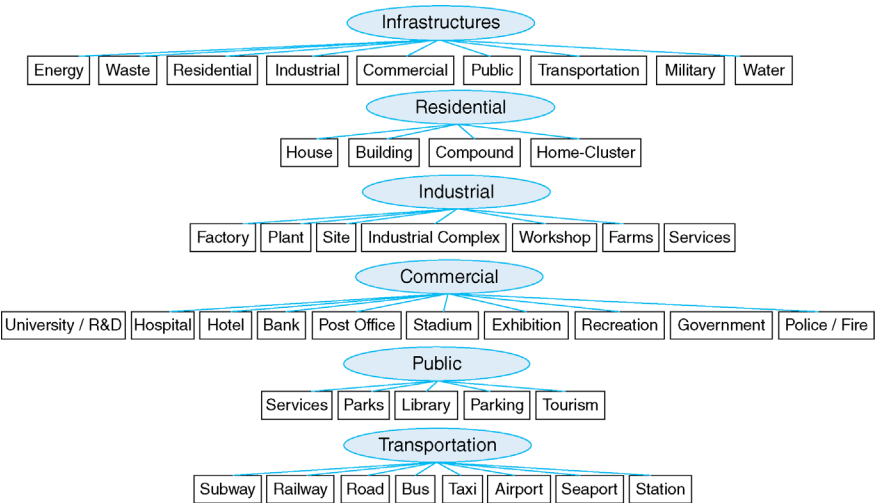


FIGURE 1.1 Infrastructure classifications.

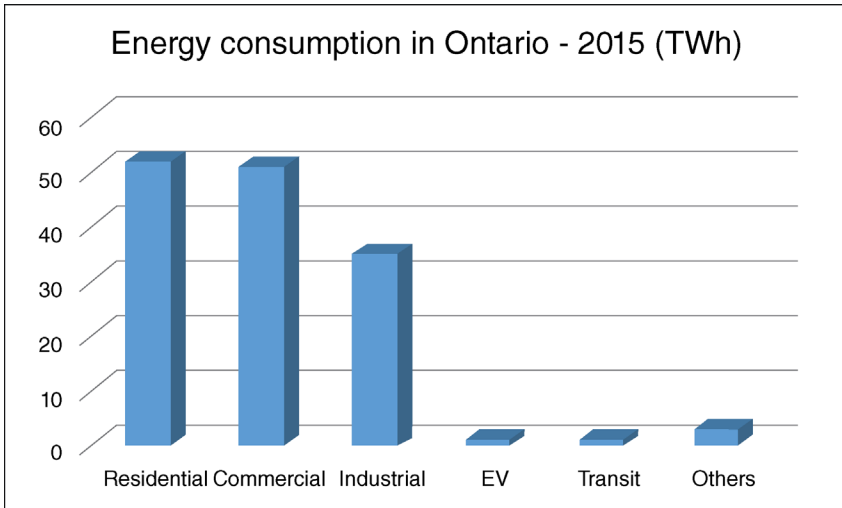


FIGURE 1.2 Power consumption in Ontario – 2015.

physical systems, functional modeling, financial modeling, planning, engineering design, operation, and management practices. One major component of infrastructure systems is the safety and protection systems to ensure the resiliency against hazardous, emergencies, and disaster situations and to sustain the stated target functions from the infrastructure systems.

1.2 ENERGY SYSTEMS IN RESIDENTIAL FACILITIES

Energy consumption in residential facilities constitutes one of the largest consumption of energy in cities and communities in Canada and worldwide. In 2015, energy consumption in residential facilities in Ontario is 52 TWh, which represents 36% of total energy consumption. Energy consumption in residential facilities include heating/cooling, electric loads, water heating, laundry, dishwashing, refrigerators and freezers, cooking, TV, lighting, and computer-related equipment, as shown in Figure 1.3. The highest energy use is in heating and cooling and ventilation, where it is clear the reduced use from 2013 to 2040. This can be justified by improved heating and cooling technologies and efficiencies. Electric loads and water heating are second largest energy use in the residential sector. Energy conservation strategies are widely adopted by utilities to reduce energy demand from utilities in residential facilities. Typically, utility grids supply energy to residential facilities. Energy conservation can represent around 1–3% of total energy demand in residential facilities. With the penetration of local distributed generation, energy can be supplied by

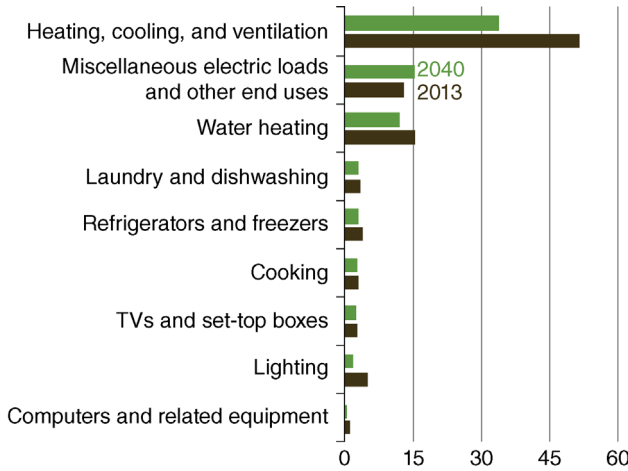


FIGURE 1.3 Residential sector delivered energy intensity for selected end uses in the Reference case, 2013 and 2040 (million Btu per household per year) [2].

renewable energy technologies such as PV, energy storage, wind, gas generators, fuel cells, and geothermal systems.

There are a number of energy systems and technologies that are adopted in residential facilities, such as gas-fired water heaters, oil-fired water heaters, electric water heaters, heat pump water heaters, instantaneous water heaters, solar water heaters, gas-fired furnaces, oil-fired furnaces, gas-fired boilers, oil-fired boilers, room air conditioners, central air conditioners, air-source heat pumps, ground-source heat pumps, gas-source heat pumps, electric resistance furnaces, electric resistance unit heaters, cordwood stoves, wood pellet stoves, refrigerators-freezers, freezers, natural gas cooktops and stoves, clothes washers, clothes dryers, and dishwashers. Among the factors that are used to evaluate these energy systems are capacity, efficiency, energy factor (EF), combined energy factor (CEF), annual energy use, annual water use, average life, retail equipment costs, installation costs, and maintenance costs. These factors are used to evaluate the different energy systems in residential facilities to ensure most effective technology that can be applied in different regions and weather conditions.

Energy consumption in residential facilities can be viewed as in Figure 1.4, where it shows different types of energy sources, such as propane, kerosene, distillate fuel oil, natural gas, renewable energy, and electricity.

It is clear that electricity and natural gas represent the highest consumption from 2012 and projected till 2040. It is also noted that losses are quite high and energy conservation strategies will be essential for effective savings.

Energy prices for residential use are shown in Figure 1.5, which shows price of natural gas (NG) is the lowest, while electricity price is the highest.

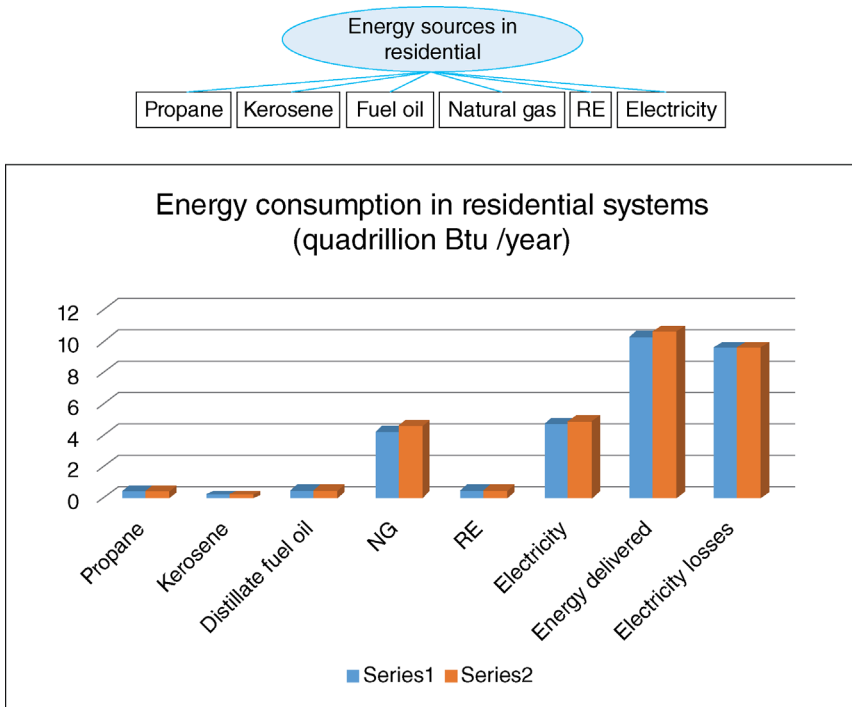


FIGURE 1.4 Energy consumption in residential systems, quadrillion Btu per year in the United States, 2012: gray, 2020: dark gray [2].

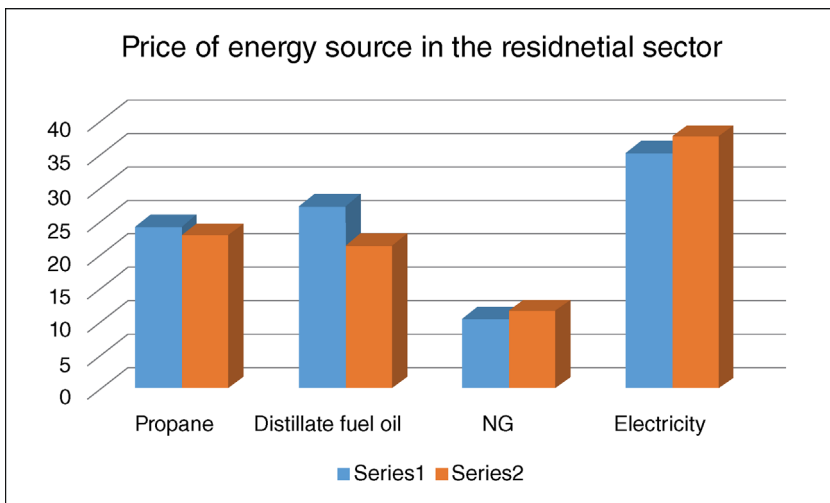


FIGURE 1.5 Energy prices in the residential sector, dollars per million Btu in the United States, 2012: gray, 2020: dark gray [2].

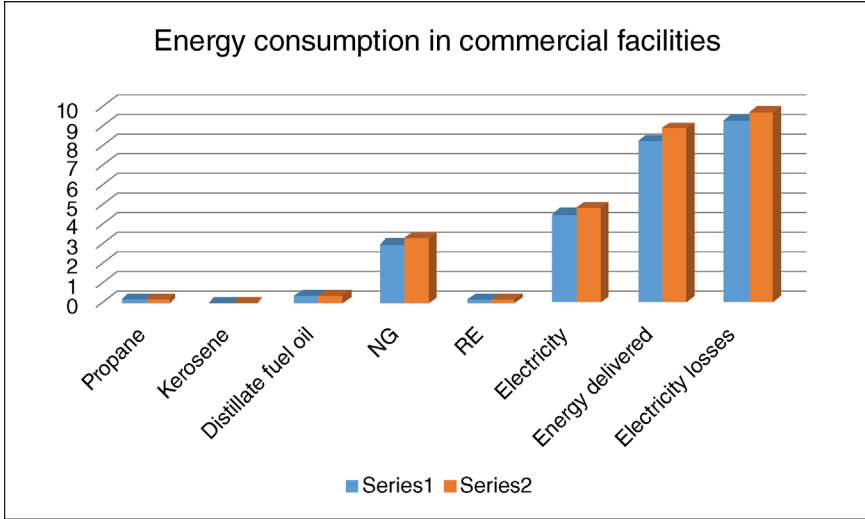


FIGURE 1.6 Energy consumption in commercial facilities in the United States, 2012: gray, 2020: dark gray [2].

1.3 ENERGY SYSTEMS IN COMMERCIAL FACILITIES

Energy consumption in commercial facilities, as stated by Department of Energy (DOE) [2], is shown in Figure 1.6. Electricity consumption is higher than NG use. While NG is cheaper than electricity, it is possible to provide better solution with increase in NG penetration in commercial use.

Also, energy prices in commercial facilities are shown in Figure 1.7.

It is shown that NG price for the residential sector is higher than NG price for the commercial sector.

1.4 ENERGY SYSTEMS IN INDUSTRIAL FACILITIES

In the industrial sector, Figure 1.8 shows the consumption from 2015 [2].

Also, energy prices in the industrial sector are shown in Figure 1.9, which shows the NG as the lowest clean energy source for the industrial sector.

1.5 ENERGY SYSTEMS IN TRANSPORTATION INFRASTRUCTURES

It is widely known that greenhouse gas (GHG) emission from transportation sector is high. The proper analysis of energy consumption in the transportation is important to address issues related to energy conservation with sustainability considerations, as shown in Figure 1.10.

Energy prices in the transportation sector are shown in Figure 1.11.

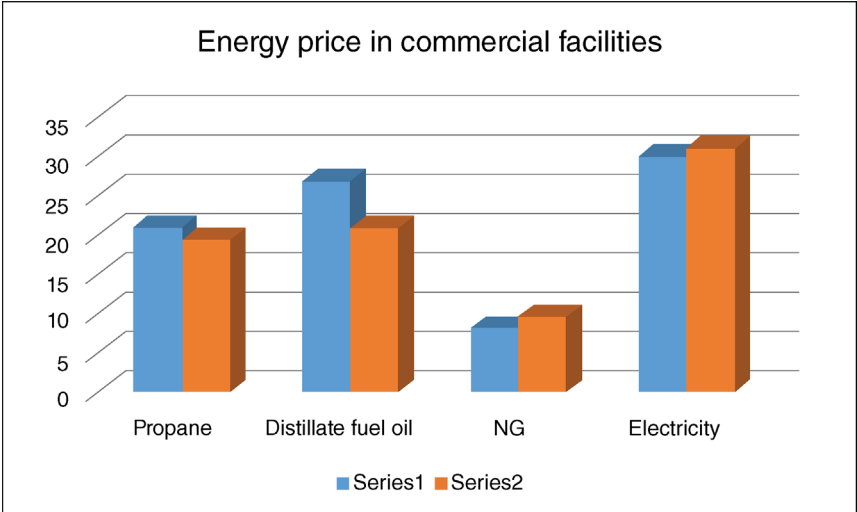


FIGURE 1.7 Energy prices in the commercial sector, dollars per million Btu in the United States, 2012: gray, 2020: dark gray [2].

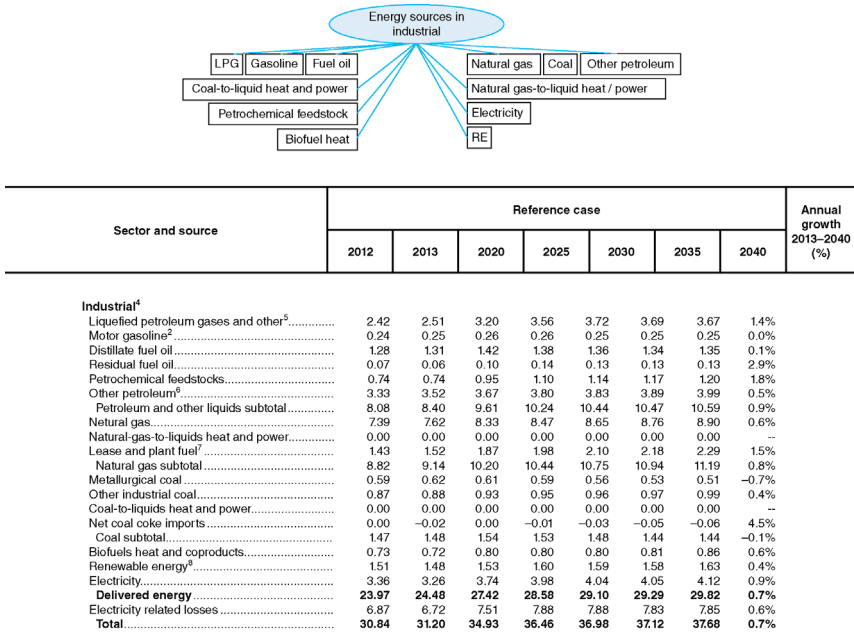


FIGURE 1.8 Energy consumption in the industrial sector [2].