Green Energy and Technology

Ming Yang
Xin Yu

Energy Efficiency

Benefits for Environment and Society

Springer

Green Energy and Technology

More information about this series at http://www.springer.com/series/8059

Ming Yang · Xin Yu

Energy Efficiency

Benefits for Environment and Society

Springer

Ming Yang
3E&T International
Beijing
China

Xin Yu
International Fund for China's Environment
Washington, DC
USA

ISSN 1865-3529 ISSN 1865-3537 (electronic)
Green Energy and Technology
ISBN 978-1-4471-6665-8 ISBN 978-1-4471-6666-5 (eBook)
DOI 10.1007/978-1-4471-6666-5

Library of Congress Control Number: 2015931804

Springer London Heidelberg New York Dordrecht
© Springer-Verlag London 2015
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Disclaimer The views, findings, interpretations, and conclusions expressed in this book are entirely those of the authors and should not be attributed in any manner to the organizations where the authors have worked.

Printed on acid-free paper

Springer-Verlag London Ltd. is part of Springer Science+Business Media (www.springer.com)

To those who contribute to a better environment

Foreword

Energy efficiency's ability to meet world energy demand and to address climate change has rapidly improved over the last decade. In many countries (developed and developing), energy efficiency has become the first fuel to meet rising energy demand and the first tool to mitigate carbon emissions. For all researchers interested in this sector, it is essential to understand the rationale for and the drivers behind this international trend.

Energy Efficiency: Benefits for Environment and Society delivers on this need. It describes the energy efficiency potential by sector (including industry, transport, commerce, and households) and indicates that while impressive efficiency gains have already been achieved over the past four decades, much more remains. It thoughtfully documents the continuing contribution of efficiency, substantiating a further 50 % reduction in energy consumption and fuel combustion-related Carbon Dioxide (CO_2) emissions if the best available technologies and policies are applied worldwide.

The volume underscores a second, equally important point: improving energy efficiency in emerging and developing economies will benefit not only these countries, but also the world. The growth of energy use in emerging and developing economies, including China, India, Mexico, Brazil, and South Africa has recently been greater than that of all other countries in the world combined. Such energy consumption growth has caused notable consequences for the rise of international energy prices and carbon emissions. With the right policies in place, the potential for energy efficiency in developing countries can be much greater potential than the Organization for Economic Co-operation and Development (OECD) countries. This means that energy efficiency improvement in developing countries can materially enhance energy security and mitigate international energy supply crises which await us if we fail to act.

All leading research authorities have concluded that energy efficiency is properly considered the first tool to mitigate climate change. The Intergovernmental Panel on Climate Change (IPCC) reports the science-based target for Greenhouse Gas

(GHG) concentration levels to be 430–480 Parts Per Million (ppm) Carbon Dioxide Equivalent (CO_2eq) by 2100 (IPCC 2014). Some climate scientists view this target as the maximum carbon concentration to stabilize global temperatures 2.0–2.4 °C above preindustrial levels and call for even lower target levels. Lowering and maintaining atmospheric concentration levels to 430–480 ppm CO_2eq by 2100 will require cuts in GHG emissions and limits on cumulative CO_2 emissions in both the medium and long term. The mitigation task is equivalent to reducing 40–70 % by 2050 compared to 2010 (IPCC 2014). In all scenarios by the IPCC, energy efficiency is key to any global effort to meet the challenge of realizing 40–70 % cuts. And one reason for this finding is clear: research reviewed by the IPCC in its latest assessment continues to find unrealized mitigation opportunities using energy efficiency that would have negative costs—it is the *only* resource which has consistently been found to offer this result.

Where are the opportunities in the case of energy efficiency? As this book reports, they are in all sectors and involve a robust menu of technologies. Investments that can be paid from guaranteeable savings include: lighting and heating technology in homes and commercial buildings, industrial and agricultural process improvements, expansion and upgrades of transit systems, and better-performing power plant technologies and on-site generation options such as Combined Heat and Power (CHP) and solar photovoltaics. National leaders are increasingly aware of the role of energy efficiency in reaching a global sustainable future. In November 2014, the presidents of the United States of America (U.S.) and China announced GHG emission targets for the two countries by 2025 and 2030. The achievement of their targets is absolutely dependent on whether energy efficiency will be used as the first tool in mitigating carbon emissions. The replacement of inefficient coal-fired power plants, a buildings-focused energy efficiency initiative, and the implementation of policies for improved transportation have enormous potential for global emission reductions in the short term, and the mutual agreement by the U.S. and China shows both nations are willing to lead the way. Science (IPCC 2014) and economics (for example, McKinsey 2010) confirm the decision by the U.S. and China to focus on energy efficiency.

Besides climate change mitigation, energy efficiency can also address some of the energy sector's vulnerabilities to climate change impacts. Energy efficiency programs aimed at peak load reduction can help counteract the increase in peak demand due to increased use of air conditioning, and address the uncertainties in generation and consumption due to extreme weather, thus helping avoid the need for additional power plants. Energy efficient buildings with special designs such as orientation, insulation, and windows are appropriately adapting to expected climate conditions. Cities can mitigate heat-island effect and reduce ambient temperatures by making efficient, cool, and green roofs for buildings. Constructing efficient CHP plants can provide secure electricity for large energy consumers or micro-grids that are less subject to grid outages due to extreme weather.

This book assembles important ideas on concepts, useful tools, and key indicators regarding energy efficiency for researchers and policy analysts. It contains a wealth of recent data and case studies that provide solid evidence of effective energy efficiency policies, technologies, processes, and practices in all end-use sectors worldwide. For this reason, it belongs on the must-read list of energy experts everywhere.

I have known Dr. Ming Yang for quite a few years, serving as a peer reviewer for his work, and joining him on panels of international conferences, including an international forum sponsored by the U.S. Department of Energy and others. He has kindly agreed to advise Ph.D. students at the Center for Energy and Environmental Policy, University of Delaware. In all aspects, I have found Dr. Yang to be the consummate professional and a scholar dedicated to rigorous analysis. This book, with his co-author, Dr. Xin Yu, meets the high standards I have seen in prior work and I am hopeful it can help the research and policy analysis community to widen our understanding of our best option for building a climate-sensitive, sustainable energy future.

Dr. John Byrne
Director and Distinguished Professor
of Energy and Climate Policy
Center for Energy and Environmental Policy
University of Delaware
Newark, DE 19716-7301, USA
Website: http://ceep.udel.edu/
Biosketch: http://ceep.udel.edu/Bios/Byrne.pdf

References

IPCC—Intergovernmental Panel on Climate Change (2014) Climate change 2014: mitigation of climate change. IPCC Working Group III contribution to AR5. http://mitigation2014.org/ Cited on January 12, 2015

McKinsey & Company (2010) Energy efficiency: A compelling global resource. http://mckinseyonsociety.com/energy-efficiency-a-compelling-global-resource/ Cited on January 12, 2015

Executive Summary

Key Components of the Book

Energy efficiency can be defined as the practice of using less energy to produce greater economic output. Energy efficiency has long been recognized as the "low-hanging fruit" in delivering a clean energy economy, especially when compared to investments in capital-intensive energy generation technologies. In its fourth and fifth assessment reports, the Intergovernmental Panel on Climate Change (IPCC 2007, 2014) shows that energy efficiency plays a major role in attaining climate stabilization targets up to 2030. However, Yang (2013) shows that a gap in energy efficiency investment has blocked progress in this direction.

An energy efficiency gap refers to the difference between levels of investment in energy efficiency that appear to be cost-effective based on engineering-economic analysis and the actual levels. The efficiency gap can also be defined as the difference between the actual level of energy efficiency and the higher level of energy efficiency that would be cost-effective from the viewpoint of an individual or a firm. The low market adoption of energy-efficient technologies, coupled with the unrealized potential, implies that significant amounts of energy could be saved cost-effectively through closing the gap. Practice showed that national governments can use policy tools to unlock energy efficiency barriers and close the gap.

Both the U.S. and China will use energy efficiency as the first tool to mitigate carbon emissions in the next two or three decades. In November 2014, U.S. President Barack Obama publicized a new target by cutting net GHG emissions of the U.S. by 26–28 % below the level of that in 2005 by the year 2025, while President Xi Jinping broadcasted that China will peak its gross CO_2 emissions by 2030. With the continued regulation effort on power generation and vehicle efficiency by the United States Environmental Protection Agency (U.S. EPA), the authors calculate and predict that the U.S. will achieve its target of reducing its total GHG emissions down to 5.2 billion tons of CO_2eq by 2025. Likewise, with energy efficiency as the first tool, China will peak its GHG emissions in 2029 at 17.1 billion tons of CO_2eq even with an 8 % per annum economic growth rate. Without energy efficiency as the first tool, it would be impossible for any of the two countries to achieve their carbon emission reduction targets.

Development and implementation of energy efficiency policies are highly correlated to oil prices, increasing energy demand and environment concerns. Almost all countries commenced energy efficiency policies after the two energy crises in the 1970s. Energy efficiency polices have successfully unlocked many market barriers and effectively closed part of energy efficiency gaps in many countries. However, many governments could do it better by fine-tuning their policies to economic and technological conditions. Some policies such as energy efficient lighting and efficient air conditioning policy can be widely adopted by many countries, but other policies, such as efficient heavy duty vehicle policy and standards, had only been adopted by Japan as of April 2014. Energy efficiency policies should encourage investors and governments to cost-effectively invest in individual markets.

Cost-effectiveness analysis on energy efficiency projects or programs is an approach used by various investors to test whether their capital investments are profitable. While undertaking such an analysis, the analyst should include all project costs and benefits quantified as cash flows throughout the lifetime of the project from investors' perspectives. It is necessary to calculate the Net Present Value (NPV) and Internal Rate of Return (IRR) of a project. If the project NPV is positive or the IRR is greater than the cost of capital of the investor, the project investment can be considered as cost-effective.

Lack of financing approaches or mechanisms in the market is a barrier to energy efficiency in most developing countries. Government policy can create effective financing approaches and mechanisms in the market to unlock this barrier. These approaches and mechanisms can be in the form of rebates, grants, or loans for energy-efficiency improvements, direct income tax deductions for individuals and businesses, and exemptions or reduced sales tax on eligible products. The application of financial approaches and mechanisms for energy efficiency financing depends on a number of characteristics including the country context, the legislative and regulatory framework, the existing energy services delivery infrastructure, and the maturity of the commercial and financial market. Some approaches and mechanisms are particularly successful in some countries but may not be so in others. Incentives offered by the national government to develop financial mechanisms are generally in the form of tax incentives. Utility companies can rebate energy efficient appliances and equipment for any energy end-users in the system, which facilitates energy efficiency investments. Dedicated credit lines, risk-sharing facilities, energy saving performance contracts, and leasing for energy efficiency financing can serve as effective approaches and mechanisms to realize energy efficiency investments. Practice has shown that these approaches and mechanisms have been successfully applied in many countries, including the U.S., Japan, China, India, and many countries in the European Union (EU). Private-sector-based Energy Service Companies (ESCOs) and individual energy end-users or customers are beneficiaries of financial mechanisms of governments and utility companies.

ESCOs are playing a very important role in energy efficiency project financing. ESCO services can cover projects in any energy area including energy extraction, power generation, energy conversion, transportation, power transmission, energy consumption, project financing, energy project audits, monitoring, and energy savings verification. In developing countries, there are many barriers in the energy market that are preventing ESCOs from developing. These barriers include lack of appropriate policy and financial mechanisms, and lack of local capacities for ESCO development and management. For ESCOs to be successful, a country needs to (1) initiate national government policy to stop energy subsidies and to reform energy pricing, (2) establish a real-market-based financial mechanism for ESCOs, (3) involve the private sector in project co-financing, (4) create incentives to ESCOs in the market by investing part of government revenue from energy tax, and (5) incentivize ESCOs by government cooperate tax exemption (Yang 2013).

When ESCOs are doing business in the energy efficiency market, the selection of technologies is also a key issue since they are the agencies to install and manage these technologies on ground. Nowadays, research, development, deployment, and investment in energy efficient technologies take place in many areas including lighting, household appliances, building envelopes, windows, doors, Heating, Ventilation, and Air Conditioning (HVAC), heat exchangers, working fluids, geothermal heat pumps, water heating, sensors and controls designed to measure building performance, smart grids, industrial processes, electrical motors, and energy efficient transport. This book briefly introduces some technologies in areas of energy efficient lighting, refrigerators, electrical motors, and vehicles. It also presents some policies to facilitate investments in several most common energy efficient technologies, and provides economic and technical guidance to ESCOs on how to choose energy efficient technologies on ground.

Urban transport is specifically described in a chapter in this book, because urban transport alone consumes nearly 8 % of world energy use, and it is one of the largest contributors to both global and local pollution. Energy efficiency in urban transport is to maximize travel activity with minimal energy consumption through a combination of land-use planning, transport modal sharing, energy intensity reducing, fuel type switching, and replacement of vehicle travels with information transmission. Different kinds of cities have different barriers to energy efficient transport modes. To achieve energy efficiency in urban transport, government policies are needed to overcome specific barriers in the market. Sustainable energy efficiency transport system needs both public and private sector investments. Public and Private Partnerships (PPP) can greatly facilitate low carbon and highly energy efficient transportation technologies. Replacing vehicle travel technologies and practices with information technologies and practices can greatly improve energy efficiency in the transport sector. Many of our daily chores now requiring transportation might be accomplished without traveling or in ways that are easier and less expensive. Two possibilities on the demand side offer the greatest promise. The first is the growing ability to move information to people instead of moving people to information, heralding an era of telecommuting, teleconferencing, telemarketing, and other trip-saving communications. The second is the design and redesign of city and suburb to substitute convenient location of urban activities for the travel that inconvenient land-use arrangements have imposed on urban residents. The future's efficient transport system in urban areas will be one that is affordable, frequent, and seamless, and that integrates information technologies, trains, bicycles, taxies, and side-walks. Such an integrated system of shared transportation options powered by energy efficient and information system is emerging.

This book is enriched with two case studies. We provide a case of raising China's motor efficiency, and also of investment in industrial energy efficient boiler systems.

Key Messages for Students, Researchers, and Practitioners

The prime messages and implications of the book are for students, researchers, and practitioners in universities, colleges, and research institutions. The fields of energy efficiency, national energy security, and climate change are creating more and more career opportunities for the young generation. A large number of colleges and universities now offer specializations in various clean energy subjects and full degree programs. Community colleges also provide training and award certificates for clean energy technicians and practitioners. Many other research organizations also offer jobs in relation to energy efficiency. Thus, this book can be used as a reference book for these organizations.

This book has several implications for students, researchers, and practitioners with different interests of professional career development. First, for those who want to be energy efficiency and climate advisors for national governments and multilateral government organizations (such as the World Bank), they need to have a sound knowledge of national, and global energy demand outlook or forecasting, and gain expertise in energy efficiency policies, climate change politics, energy economics, and energy efficient technology development and transfer. Second, for those who want to run their own energy service companies, they must have in-depth knowledge in project economic and financial analysis, project financing, energy efficient technology acquisition, equipment installation, operation, and project evaluation. Third, for those who want to become energy managers in any industrial and commercial firms, they must have a strong educational background and work experience in energy engineering, technologies, economics, finance, equipment operations, energy savings monitoring, auditing, verification, and reporting. It is recommended that a university student build up his/her knowledge and skills and expand his/her interest in multiple fields. Today, this world needs talents in energy and climate change politics, economics, finance, engineering, technologies, and management; it badly needs talents whose expertise and experience cover all the above mentioned areas!

Key Messages for Governments

The second key message of the book is for governments. Saving energy through energy efficiency improvements can cost less than generating, transmitting, and distributing energy from power plants, and provides multiple economic and environmental benefits. Bringing more energy efficient technologies to an economy will not only significantly reduce energy demand, increase national energy security, but also put more money back in the pockets of individual companies and households. Energy efficiency also helps reduce local air pollution and GHG emissions, and creates jobs. Governments can promote energy efficiency in their jurisdictions with policies.

As governments design their policy framework to support their energy efficiency and climate change mitigation goals, they need to start by defining the overall energy efficiency or emission-reduction ambition goals or targets through an effort-defining policy. This may include reducing energy intensity (energy consumption per unit of Gross Domestic Product (GDP) output) and carbon intensity (CO_2 emission per unit of GDP output) by some percentage or cap energy consumption or carbon emissions at some levels. The goals should be not only in quality and scope, but also in quantity of effort-defining. When national mandatory energy efficiency targets are clear, sectoral targets such as energy efficient white certificate schemes, industrial product/process standards, building codes, minimum efficiency standards for vehicles, etc., can be developed and improved for individual industrial, commercial, and residential sectors.

To define ambitious energy efficiency or GHG-reduction goals, governments need to identify barriers that lock energy efficiency investments from the private sector. When these barriers are identified, supporting measures, in the form of carrots or sticks, are often needed to support the effort-defining policies and encourage action. The choice and design of these supporting measures depend on the specific barriers of the country and sector, their interaction with other policies, and the political and cultural characteristics of the country.

A comprehensive implementation action plan and capacity are needed to support the implementation and achievement of the government effort-defining policies and strategies. An ideal situation is that a country sets energy efficiency policy, simultaneously develops a set of supporting measures and an implementation action plan, and build up capacity to implement the plan. In some cases, when policies and measures have been established, guidelines are developed and implementation action plans follow.

When a policy or strategy is under implementation, a transparent monitoring, reporting, and verification process is necessary to assess the effectiveness of the policy, allow ongoing evaluation and possible adjustment of the policy, and build trust. Governments need to identify parameters and indicators that will be monitored to allow ongoing and ex-post evaluations. Policy efficiency and free riding should be assessed, in addition to effectiveness, in ex-post policy evaluation. This is to ensure that the policy is achieving the desired goals at the lowest costs to the economy as well as the targeted group.

Key Messages for Project Developers

Usually, the development of energy efficiency projects involves a large number of stakeholders and decision-makers. Many of these developers are directly involved in project preparation, design, implementation, and evaluation; they consequently often determine project outcome. This book helps project developers to understand energy efficiency project investment and implementation cycles including project initiatives, identification, development, finance, implementation, reporting, and post-evaluation.

ESCOs are strongly affected by national government energy efficiency policies and energy prices on ground. Where there is strong national government policy initiative in energy efficiency investment and there are energy saving targets for individual economy sectors, there is a market for blooming ESCO business. By contrary, if a market is full of fossil energy subsidies, ESCO business cannot survive. Energy efficiency project developers need to forecast new government policy initiatives, energy price changes, and advancements of energy efficient technologies.

Key Messages for Developing Countries

Based on the two case studies, this book derives several key messages for developing countries. First, developing countries' business and political environments can have major impacts on project development, and should consequently be considered during project planning and identification. If a country is not politically stable, any good energy efficiency project will have difficulties in achieving its goal. Second, co-financing for energy efficiency projects is a very important indicator for project quality. A good energy efficiency project will likely attract more co-financing from various project stakeholders, particularly from the private sector. Third, an appropriate government energy policy should be available to support or facilitate duplications or self-development of new or transferred energy efficiency technologies. Fourth, continued capital investments in research and development should be committed from the private sector after project completion. If these conditions are not met, the investments in energy efficiency projects in developing countries may not operate adequately in the long run.

References

IPCC—Intergovernmental Panel on Climate Change (2007) IPCC fourth assessment report: climate change 2007 (AR4). http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml. Accessed 29 Nov 2011

IPCC—Intergovernmental Panel on Climate Change (2014) Climate change 2014: mitigation of climate change. IPCC Working Group III contribution to AR5. http://mitigation2014.org/

Yang M (2013) Closing the gap: GEF experiences in global energy efficiency. Springer, Berlin. ISBN: 978-1-4471-4515-8; ISBN 978-1-4471-4516-5 (eBook). Library of Congress Control Number: 2012947854. http://www.springer.com/engineering/energy+technology/book/978-1-4471-4056-6

Contents

About the Authors

Dr. Ming Yang is senior climate change specialist in the Global Environment Facility headquartered in Washington D.C. of the USA. He used to work in the International Energy Agency in Paris and in the Asian Development Bank in Manila, the Philippines. He was author for three books: (1) Closing the Gap (2013), (2) Negotiation in Decentralization (2012), and (3) Climate Policy Uncertainty and Investment Risk (2007); and contributing author for three books: (1) Energy Technology Perspectives (2008), (2) Light's Labor's Lost (2006), and (3) and Policy Support for the PRC 2020 (2003). In addition, he has authored chapters for two books, 45 peer-reviewed journal papers and 65 short newspaper articles in fields of energy and climate change. Dr. Yang holds Ph.D. in energy economics, M.S. in power economics, and B.S. in electric power engineering.

Dr. Xin Yu is consultant in the International Fund for China's Environment (IFCE). Prior to joining the IFCE, she was research fellow and research assistant in three Australian universities for 10 years. Her expertise covered not only energy and environment, but also higher education teaching, learning, and assessment. She played a key role in writing a number of research reports and teaching and learning resource materials for instructors and students. Before that, she worked as news editor for Asian Energy News, a monthly journal in energy and environment, for 44 issues in a period of five years. She has coauthored three books and more than 20 refereed journal articles in energy, tourism and higher education. Dr. Yu holds Ph.D. in management.

Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AFOLU	Agriculture, Forestry, and Other Land Use
BCR	Benefit-Cost Ratio
BRT	Bus Rapid Transit
CDI	Capacity Development Initiatives
CEEF	Commercializing Energy Efficiency Finance
CFL	Compact Fluorescent Lamp
CHEEF	China Energy Efficiency Financing
CHUEE	China Utility-Based Energy Efficiency Finance Program
CIF	Climate Investment Fund
CO_2	Carbon dioxide
CSOs	Civil Society Organizations
DOE	Department of Energy
DSM	Demand-Side Management
DPP	Discounted Payback Period
EBRD	European Bank for Reconstruction and Development
ECF	Energy Conservation Promotion Fund
EJ	Exajoule (10^{18} joules)
EMC	Energy Management Company
ESCO	Energy Service Company
ESPCs	Energy Savings Performance Contracts
EST	Environment Sound Technologies
EU	European Union
GEF	Global Environment Facility
GFA	Guaranteed Facility Agreement
GHG	Greenhouse Gas
$GtCO_2e$	Giga tons of CO_2 equivalent
GW	Gigawatt (1,000 MW)
HAVC	Heat Ventilation and Air-Conditioning
IADB	Inter-American Development Bank

IEA	International Energy Agency
IEG	Independent Evaluation Group
IFC	International Finance Corporation
IFIs	International Financial Institutions
IMC	Intelligent Motor Controller
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
LED	Light-Emitting Diode
LULUCF	Land-Use, Land-Use Change, and Forestry
M&V	Monitoring and Verification
MPG	Miles Per Gallon
MPGe	Miles Per Gallon Equivalent
MOF	Ministry of Finance
$MtCO_2e$	Million tons of CO_2 equivalent
MWh	Megawatt hour
NMT	Non-motorized Technologies
NPV	Net present value
OECD	Organization for Economic Cooperation and Development
PLG	Project Leading Group
PMO	Project Management Office
ppm	Parts Per Million
PPPs	Public and Private Partnerships
rpm	Revolutions Per Minute
SIDBI	Small Industries Development Bank of India
SME	Small and Medium Enterprises
SO_2	Sulfur Dioxide
SSL	Solid State Lighting
SUT	Sustainable Urban Transport
T&D	Transmission and Distribution
TEERF	Thailand Energy Efficiency Revolving Fund
TSP	Total Suspended Particulates
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNF	United Nations Foundation
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US	The United States of America
WB	The World Bank
YKL	Yapi Kredi Leasing

Chapter 1
Introduction

Abstract Energy efficiency is no longer a new term for the public. Over the past four decades, the concept of energy efficiency has been more and more accepted and used by the society worldwide. Along with energy efficiency, some other relevant terms such as energy conservation, energy intensity, and energy savings have also been frequently used. This chapter presents a brief introduction on these terms and a short description on relationship among energy efficiency, climate change, global energy demand, and national energy security. This chapter also introduces the concepts of energy efficiency gap, low hanging fruits of energy efficiency, and energy efficiency barriers.

1.1 Basic Concept and Definitions

The concept of **energy efficiency** has been developed since the first energy crisis in 1973. Lovins (1976) was among the first to develop a definition of energy efficiency: using less energy to produce greater economic output. It can be expressed as a ratio of useful outputs to energy inputs for a system. The system may be an individual energy conversion device such as a boiler, a building, an industrial process, a firm, a sector, an entire economy, or the whole world. It can also be expressed as a qualitative concept. This book uses the definition defined by Lovins (1976) since the case studies of the book are about energy savings under a condition that provides the same output value of goods and services.

Energy conservation is different from energy efficiency. Energy conservation is to reduce energy consumption without keeping comfortable life or without maintaining same productivities. In buildings, for example, being mindful about turning lights off, when daylighting is sufficient, is to conserve energy; replacing an incandescent lamp with a light-emitting diode (LED) lamp that uses much less energy to produce the same number of lumens is to increase energy efficiency. Energy efficiency and energy conservation are both able to save energy and cut energy bills.

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_1

Energy intensity is a widely used indicator to measure energy efficiency, generally defined as primary energy consumption per unit of economic output. It is usually expressed as tonnes of oil equivalent (toe), or tonnes of coal equivalent (TCE), or mega joules per thousand dollars of GDP. For example, China uses TCE per 10 thousand Chinese Yuan, while the International Energy Agency (IEA) uses tonnes of oil equivalent per thousand US dollars to measure energy intensity.

Energy savings are results of energy efficiency investments and management. They come from both energy use sectors including households, transport, buildings, industry, agriculture, and energy supply and conversion systems such as coal exploitation, power generation, and oil and gas extraction and refineries. These savings can be grouped into five broad categories: (1) savings due to high energy prices (the higher the energy prices, the lower demand for energy services and final energy consumption); (2) savings due to fuel and energy technology switching (switching electric heaters to heat pumps for space heating reduces final electricity consumption); (3) savings due to economic structure changes (developing service industry to replace heavy and manufacturing industries such as iron and cement industries); (4) savings due to energy efficiency improvements (replacing a single-glazed window with double- or triple-glazed window in a building); and (5) savings due to information technology and smart grid management (global positioning system and smart grid technologies have significantly saved energy in transport and power generation systems).

Energy efficiency activities refer to any practice or efforts that are related to saving or conserving energy. Some energy efficiency activities are tangible and some are intangible. Tangible energy efficiency activities usually involve capital investments, and intangible activities involve policy and regulatory framework development, capacity building, and institutional enhancement. Results of tangible energy efficiency activities can be easily identified. In buildings, for example, when a single-glazed window is replaced with a double-glazed window, the new window prevents heat from escaping in the winter, which helps use less energy for space heating while keeping the comfortable life unchanged. In the summer, the double-glazed window also keeps heat out; the house air conditioner does not run as often and electricity consumption for the house is saved. On the contrary, results of intangible energy efficiency activities cannot be easily identified. For instance, impact of new energy efficiency policy in a country can hardly be measured in a short time.

Energy efficiency policies are the policies that are developed for the purpose of improving energy efficiency. These policies can improve national energy security, increase industrial competitiveness, cut household energy bills, and reduce problems that are linked to local air pollution and climate change. However, quantifying benefits or achievement of energy efficiency policies is not an easy task since energy efficiency policies usually involve a variety of energy services across different sectors—including buildings, industry, commerce, and transport.

1.2 Energy Efficiency and Climate Change Mitigation

Intergovernmental Panel on Climate Change (IPCC 2001) defines climate change as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change from human-induced emissions of heat-trapping GHGs is a critical global issue and requires substantial actions for mitigation. GHG emissions mitigation involves reductions in the concentrations of GHGs, either by reducing their sources or by increasing their sinks through sequestrations. Approaches to mitigating GHG emissions therefore include reducing demand for emission-intensive goods and services, increasing efficiency gains, increasing use and development of low-carbon technologies, and reducing fossil fuel emissions (Stern 2007).

Energy efficiency contributes to climate change mitigation via reducing energy consumptions and hence GHG emissions. Improving energy efficiency has widely been accepted as a cost-effective approach to mitigating GHG emissions. In its Fifth Assessment Report, the IPCC (2014) shows that energy efficiency plays the second largest role in attaining climate stabilization targets up to 2030.

In its World Energy Outlook, the IEA (2013) estimates that in 2020, energy efficiency will be responsible for 50 % of the energy-related CO_2 emissions abatement necessary to bring down CO_2 concentration to the level compatible with limiting the long-term temperature increase to 2 °C, which is equivalent to 450 CO_2 ppm. The IEA (2013) proposed a scenario to reduce 5.9 Gt of GHG emissions between 2010 and 2030 by using eight measures. Energy efficiency which is the most effective measure to GHG emission reduction contributes to 42 % (Fig. 1.1).

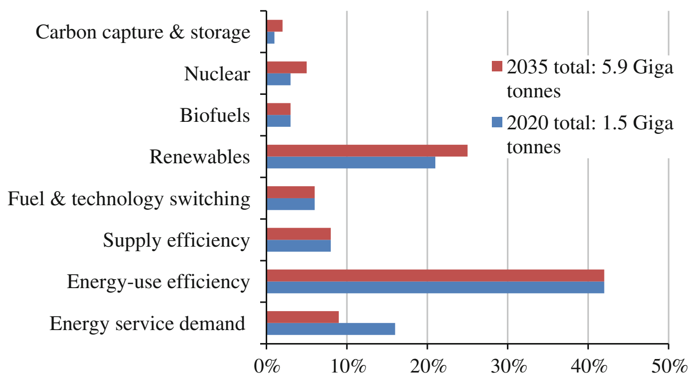


Fig. 1.1 Projection of GHG emission reduction by technologies. *Source* Authors developed chart from IEA data (2013)

1.3 Energy Efficiency, Global Energy Demand, and Environment

Improved energy efficiency can realize huge gains for the global environment. These gains are not based on achieving any new or unexpected technological breakthroughs, but just on taking actions to remove barriers obstructing the investment, deployment, development, and implementation of energy-efficient technologies that are economically viable. Successful action to this effect would have a major impact on global energy and climate change mitigation. According to IEA (2012), if governments implement new policies as suggested in its New Policy Scenario, the growth in global primary energy demand from 2014 to 2035 would be reduced by 50 %. Oil demand would peak just before 2020 and would be almost 13 million barrels per day (mb/d) lower by 2035, a reduction equal to the current production of Russia and Norway combined, easing the pressure for new discoveries and development. Additional investment of US$11.8 trillion (in 2011 constant price) in more energy-efficient technologies would be more than offset by reduced fuel expenditures. The accrued resources would facilitate a gradual reorientation of the global economy, boosting cumulative economic output to 2035 by US$18 trillion, with the biggest GDP gains in India, China, the USA, and Europe. The goal of sustainable energy for all (or universal access to sustainable energy) would be easier to achieve. Energy-related CO_2 emissions would peak before 2020, with a decline thereafter consistent with a long-term temperature increase of 3 °C. Targets for air quality improvement for cities will be achieved easily, as emissions of local pollutants fall sharply.

1.4 Energy Efficiency—Low Hanging Fruits

Energy efficiency has long been recognized as the “low hanging fruits” in delivering a clean energy economy, especially when compared to investments in capital-intensive energy generation technologies. According to the US Department of Energy (DOE), buildings account for approximately 40 % of total US energy costs, which amounts to US$400 billion each year for residential and commercial buildings alone. Reducing energy use in US buildings by 20 % would save approximately US $80 billion annually on energy bills, and savings from commercial buildings would account for half of this amount, or US$40 billion. Tapping into this enormous potential for energy efficiency projects to cost effectively lower energy consumption would help create new investment opportunities, drive economic growth, reduce air pollution and greenhouse gas emissions, increase economic efficiency and productivity, create jobs, and advance national energy security. Despite these benefits, advanced energy efficiency improvements and technologies have not yet been widely adopted (U.S. DOE 2012).

The IEA (2007) estimated the low hanging fruits of energy efficiency to be in the range of approximately 20–50 % of the total final energy consumption in the world. Energy efficiency policies in 11 OECD countries (USA, Japan, Australia, UK, France, Italy, Germany, Denmark, Norway, Sweden, and Finland) between 1973 and 1998 had saved approximately 49 % of the actual energy use. Jollands et al. (2010) showed that energy efficiency policies would help save an average of 20 % of the final energy consumption from 2010 to 2030 in five major sectors, namely buildings, equipment, lighting, transport, and industry, in OCED countries. If other sectors are considered, low hanging fruits of energy efficiency would be more than 20 %. A review of the IEA literature on low hanging fruits of energy efficiency in the past and the future demonstrates that energy efficiency potentials in selected IEA/OECD countries from 1975 to 2030 would be within a range of 20–50 %. The energy efficiency fruits in developing countries could be hanging lower than IEA/OECD countries because of the widespread use of inefficient energy technologies. Why has the world not picked all energy efficiency low hanging fruits? There must have been some barriers that prevent the government, the private sector, and other energy efficiency market players from picking up the low hanging fruits.

1.5 Energy Efficiency Barriers

In theories of competition in economics, barriers to entry are obstacles that make it difficult to enter a given market (Sullivan et al. 2003). The term can refer to hindrances a firm faces in trying to enter a market or industry—such as government regulation and patents, or a large, established firm taking advantage of economies of scale—or those an individual faces in trying to gain entrance to a profession—such as education or licensing requirements.

In this book, energy efficiency barriers are defined as obstacles that prevent or impede the investments and diffusion of cost-effective energy-efficient technologies or practices in the market. These barriers include high transaction costs, invisibility of energy efficiency investment results, misplaced incentives, lack of access to financing, mispricing imposed by regulation, gold plating and inseparability of features of energy-efficient technologies, externalities, imperfect competition, public goods, imperfect information, and customer inertia. Energy barriers cause market failures and lead to energy efficiency gaps.

1.6 Energy Efficiency Gap

Energy efficiency gap refers to a difference between levels of investment in energy efficiency that appear to be cost-effective based on engineering-economic analysis and the lower levels of investments actually occurring (SERI 1981). Efficiency gap can also be defined as a difference between the actual level of energy efficiency and the higher level that would be cost-effective from individuals' or firms' point of view. In this book, both of the definitions are applicable since this book covers scopes in investment analyses and firms' operations in using energy. Current low market adoption of energy-efficient technologies coupled with the unrealized energy efficiency potential implies that significant amounts of energy could be saved cost effectively through closing the energy efficiency investment gap.

However, it is difficult to forecast how much capital should be invested in global energy efficiency to fill the energy efficiency gap. Investments in global energy efficiency depend on many factors including the GHG emissions mitigation targets set by the international community, future oil prices, climate change policies of national governments, and breakthroughs in energy efficiency technologies. Many international organizations and individuals have attempted to estimate worldwide capital investments for closing energy efficiency gaps. These include the European Environment Agency (EEA 2005), Argonne National Laboratory (Hanson and Laitner 2006), and the Asian Development Bank (ADB 2006), Chantanakome (2006), and Shen (2006).

The IEA (2006) developed an Alternative Policy Scenario for a portfolio of clean energy technologies and policies. The capital investment costs of these technologies and policies would be more than outweighed by the benefits from producing and using energy more efficiently. The IEA Alternative Policy Scenario estimates that, on average, an additional US$1 invested in more efficient electrical equipment, appliances, and buildings avoids more than US$2 in investment in electricity supply. These savings are particularly valuable in economies where the lack of capital is a constraint to economic growth. The IEA (2006) also projects that a total of additional US$2.4 trillion on top of its business-as-usual scenario is needed to improve energy efficiency in three major sectors to address the energy efficiency gap until 2030 worldwide. Investment in the transport sector would increase by US $1.1 trillion, which is close to half of the total additional energy efficiency investments in all sectors in the world. Investment in the residential and services sectors (including agriculture) is approximately US$0.92 trillion higher than the business-as-usual scenario, while the industrial sector has an extra investment of US $0.36 trillion. In brief, the IEA analysis says that from 2014 to 2030, the world needs to invest approximately US$96 billion per year (US$2.4 trillion divided by 25 years) to fill the energy efficiency gap in the industrial, transport, residential, and commercial sectors.

The actual energy efficiency gap from a societal perspective is even larger than IEA's prediction. In a society, large institutions and utilities have obligation to serve end users, using their borrowing capacity to underwrite energy efficiency investments foregone by end users. Negative externalities, such as environmental costs associated with the discovery, acquisition, refining, transportation, and consumption of energy, are mainly paid by these institutions and utilities, which increases risk of investment and decreases capital investments of the society. This implies that, from a social perspective, the energy efficiency gap in a society is larger than it appears from the perspective of an individual end user in the market.

1.7 Methodologies

This book is based upon work experiences and early publications of the authors, together with a review of recent studies of energy efficiency drawn from the literature. These studies were published after 1973 since the first discussion or debate on energy efficiency as a hidden fuel. The focus of this book throughout is upon energy efficiency, although some of the studies also include climate change mitigation and energy security. The book includes quantitative summaries of the results of these recent studies, together with more detailed examinations on empirical research methodologies.

1.8 Objective

This book reviews and presents energy efficiency related issues and measures to resolve these issues. The objective of this book is to enhance knowledge of energy efficiency for students and young professionals from perspectives of national energy security, government laws and policies, technologies, engineering, finance, and on-ground equipment operations. This book can be used as a reference book for students who want to become policymakers in energy and climate change, energy efficiency project/program financiers and economists, developers and managers for energy efficiency projects, and practitioners to operate energy-efficient technologies on ground.

1.9 Book Structure, Conclusions, and Recommendations

This book consists of 13 chapters. Following the introduction, Chap. 2 reviews literature on energy efficiency changing from the hidden fuel to the world's first fuel, Chap. 3 describes the importance of energy efficiency as first tool for climate change mitigation, and Chap. 4 lists market barriers to energy efficiency as the second part of the literature review. Overall methodology used in this study is presented in Chap. 5. Most widely used energy policies to harness the world's first fuel and unlock energy efficiency barriers are presented in Chap. 6. With the economic and financial theory and applications, Chap. 7 elaborates methodologies and approaches for cost-effective test, Chap. 8 presents energy efficiency financing, and Chap. 9 demonstrates how ESCOs and energy performance contracting (EPCs) effectively facilitate private sector investments in energy efficiency industry. Discussed in Chap. 10 are the different energy-efficient technologies including lighting, appliances, vehicles, electric motors, and industrial processes. Energy-efficient urban transport activities including government and the private sector are analyzed in Chap. 11. This book also presents, in Chap. 12, two case studies that cover (1) China's experience in raising efficiency of electrical motors; and (2) improving efficiency by investing in global industrial boilers. In the last chapter, this book concludes and recommends the following for academia, government policymakers, policy implementation agencies, project developers, and financiers:

1. University students and researchers should build up their knowledge and expand their interest in multiple fields while preparing their future career development in energy efficiency and climate change;
2. Appropriate government energy efficiency policies, standards, and regulations should be given highest priority in promoting energy-efficient investments;
3. A comprehensive implementation action plan and capacity building are essential to support the implementation and achievement of the government policies and strategies;
4. Energy efficiency project developers should have capacity and vision to forecast new government policy initiatives, energy price changes, and advancement of energy-efficient technologies;
5. While planning investments in energy efficiency, an investor should choose a country with four conditions: (1) The political situation is stable, (2) co-financing for energy efficiency projects is not difficult to raise from the country, (3) government energy policy supports or facilitates duplications or self-development of new or transferred energy efficiency technologies, and (4) the private sector is willing to invest in research and development of energy-efficient technologies in the country.

References

ADB—Asian Development Bank (2006) Report of the energy efficiency initiative. ADB, Manila. http://developmentasia.org/Documents/Reports/Energy-Efficiency-Initiative/execsum.pdf. Cited on 26 Apr 2012

Chantanakome W (2006) "ASEAN country experiences in promoting energy efficiency", presentation at the Energy Efficiency Investment Forum, May, New York. http://www.gfse.at/fileadmin/dam/gfse/gfse7/ESMAP_EnergyEfficiencyInvestmentForum2006.pdf. Cited on 26 Apr 2012

EEA—European Environment Agency (2005) Climate change and a European low-carbon energy system, EEA, Copenhagen. EEA report no 1/2005. ISBN: 92-9167-765-5

Hanson DA, Laitner JA (2006) The Amiga modelling system, version 4.2: disaggregated capital and physical flows of energy within a general equilibrium framework. A user manual published by Argonne National Laboratory, Argonne, Illinois, USA

IPCC—Intergovernmental Panel on Climate Change (2001) Climate change 2001: impacts, adaptation, and vulnerability. http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=663. Accessed 24 May 2012

IPCC—Intergovernmental Panel on Climate Change (2014) Climate change 2014: mitigation of climate change. IPCC Working Group III Contribution to AR5. http://mitigation2014.org/

IEA—International Energy Agency (2006) World energy outlook, Paris. ISBN: 92-64-10989-7-9

IEA—International Energy Agency (2007) Lights labour's lost. OECD, Paris. https://www.iea.org/publications/freepublications/publication/name,3644,en.html

IEA—International Energy Agency (2012) Energy efficiency definition. http://www.iea.org/subjectqueries/keyresult.asp?keyword_id=4122. Accessed 18 Jan 2012

IEA—International Energy Agency (2013) Energy efficiency 2013: market report, market trends and medium-term prospects

Jollands N, Waide P, Ellis M, Onoda T, Laustsen J, Tanaka K, T'Serclaes P, Barnsley I, Bradley R, Meier A (2010) The 25 IEA energy efficiency policy recommendations to the G8 Gleneagles plan of action. Energy Policy 38(11):6409–6418

Lovins A (1976) The road not taken? energy strategy: friends of the earth's not man apart. Spec Reprint Issue 6(20):1977

Shen L (2006) Advancing more banks entering into the field of energy conservation by using new energy conservation mechanisms. In: International conference on financial intermediation mechanisms for energy efficiency in Brazil, China and India, Paris. http://3countryee.org/paris/AgendaParisEEconf.pdf. Cited on 26 Apr 2012

Sullivan A, Sheffrin S, Wiggins G (2003) Economics: principles in action. Pearson Prentice Hall, Upper Saddle River, p 153. ISBN: 0-13-063085-3

SERI—Solar Energy Research Institute (1981) A new prosperity: building a sustainable energy future. Brick House Publishing, Andover

Stern N (2007) Stern review on the economics of climate change: Part III: the economics of stabilization. http://hm-treasury.gov.uk/sternreview_index.htm. Accessed 1 Dec 2011

U.S. DOE—U.S. Department of Energy (2012) Buildings energy data book, March 2012. http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx. Citied 25 July 2014

Chapter 2
Energy Efficiency Becomes First Fuel

Abstract Energy efficiency can be defined as an energy resource because energy efficiency is capable of yielding energy and demand savings that can displace electricity generation from primary energy resources. Investments in energy efficiency and the resulting resource benefits are factored directly into utility energy resource decision making about investing in new resources and operating existing systems. Defining energy efficiency as a resource and integrating it into utility decision making is especially critical because of the clear resource cost advantage of energy efficiency. Energy savings from customer energy efficiency programs are typically achieved at one-third of the cost of new generation resources. Efficiency programs can also reduce the need to install, upgrade, or replace transmission and distribution equipment. In addition, energy efficiency when integrated with smart grid technologies can improve system reliability and allow utilities to reduce and manage peak demand in their power systems. Finally, energy efficiency will reduce fossil fuel consumption and increase energy security; it is indeed considered the first fuel now by many countries.

2.1 History of Energy Efficiency—A Hidden Fuel

Prior to the first energy crisis in 1973, there was little discussion on energy efficiency. Oil had been cheap, and discoveries of new oil fields offered a promise of many years of sustainable oil supply. However, Meadows et al. (1972) pointed out that finite resource supplies could not sustainably support the exponential economic and population growth. In their book, Meadows and his co-authors (1972) used a computer model (the world model) to simulate the consequence of interactions among world population, industrialization, pollution, food production, and resource depletion, presented a new intellectual trend for human beings to use limited resources efficiently. In 1973, the Arab oil embargo to the Western industrialized countries awaked concerns about threats to national energy security for oil-importing countries. This new vision saw that increasing energy demand along with

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_2

shortages of fossil fuel supplies would threaten economies built on the promise of cheap energy, and oil-importing countries would have to seek efficient use of energy.

Lovins (1976) articulated the implication of the new vision for energy efficiency policy in *Energy Strategy: The Road Not Taken.* The paper described alternative sources of energy that were plentiful, renewable, and more environmentally benign than fossil fuels. The key point of Lovins's argument was the development of the concept of energy efficiency: using less energy to produce more economic output. "*My own view is that we are adaptable enough to use technical fixes alone to double, in the next few decades, the amount of social benefit we wring from each unit of end-use energy. Then over the period 2010–2040 we should be able to shrink per capita primary energy use to perhaps a third or a quarter of today's*" (Lovins 1976). Soon after the publication of this paper, ideas about energy efficiency as a fuel began having a significant effect on government policies.

Energy efficiency as a fuel contributed the largest share of "energy use" in the first 11 IEA member countries. The IEA estimated that energy efficiency policies in its first 11 member countries (Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, UK, and USA) saved approximately 65 % actual energy use in 2010 (Fig. 2.1). Since 1974, energy efficiency in the 11 countries avoided burning of 1.5 billion tonnes of oil equivalent. Between 2005 and 2010, these 11 countries made energy bills equal to US$420 billion, and the saved energy is more than what any other single fuel source provided. In 2010, energy efficiency as a fuel met 65 % of total final consumption of energy in the 11 IEA member countries.

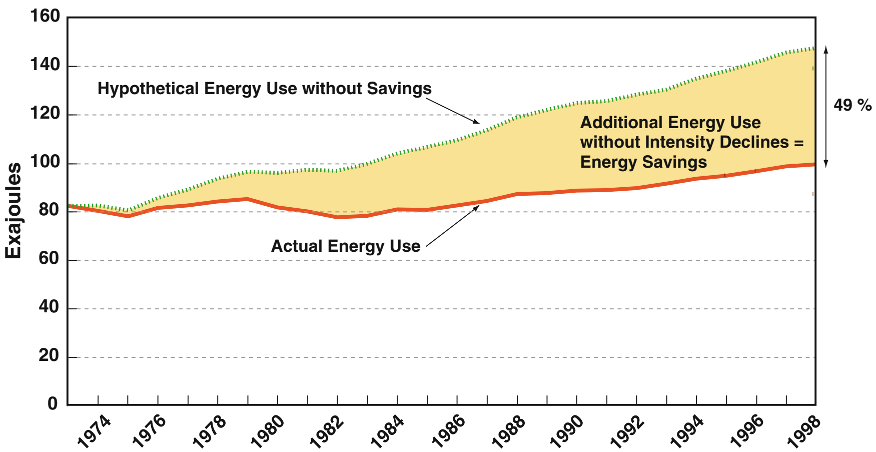


Fig. 2.1 Impact of energy policy on energy efficiency improvement in IEA countries. *Source* Yang (2013)

Without these energy efficiency measures implemented from 2010 to 2013, consumers in these 11 countries would have been paying two-thirds more than they paid for their energy bills (IEA 2013b).

However, despite being the most cost-effective and clean energy resource, energy efficiency was not always treated as the first fuel. In energy and power expansion planning, people kept forgetting it as a resource of energy supply against coal, oil, and natural gas. Energy efficiency was not included in any country on the list of the "all of the above" energy policies and strategies discussed in public discourse and government energy plans. Indeed, in the global phenomenon, energy efficiency was referred as a "hidden fuel" before 2010.

2.2 Energy Efficiency as the First Fuel

The IEA estimated the efficiency potentials at a range of approximately 20 to 50 % of total final energy consumption. According to IEA (2007), energy efficiency policy in 11 OECD countries between 1973 and 1998 had saved approximately 49 % of energy use (Fig. 2.1). Jollands et al. (2010) showed that energy efficiency policy will be able to help save an average of 20 % of final energy consumption from 2010 to 2030 in five major sectors, namely buildings, equipment, lighting, transport, and industry in OECD countries. IEA (2013a) stressed that energy efficiency should be treated as "the first fuel" rather than "the hidden fuel." It also indicated that global energy efficiency investments and their effects on energy supply are now equal to the net contribution of other energy resources. "Energy efficiency has been called a 'hidden fuel', yet it is hiding in plain sight," IEA Executive Director Maria van der Hoeven said as she presented an IEA report at the Second World Energy Congress in Korea in 2013. "Indeed, the degree of global investment in energy efficiency and the resulting energy savings are so massive that they beg the following question: Is energy efficiency not just a hidden fuel but rather the world's first fuel?" (IEA 2013b).

2.3 The First Fuel Never Runs Out

There is always a potential to enlarge the first fuel in any country or any sector due to at least three driving factors. First, energy prices are generally growing all the time since the energy resources are limited and energy demand is increasing. Second, government policies on energy and climate change always require industries, businesses, and the households to adapt stricter and high energy standards and codes. Third, energy-efficient technologies, products, and equipment are always invented and made to harness the first fuel, either in developed or developing countries. These factors drive countries to move toward being more and more energy efficient, regardless how efficient the country is already.

For example, Japan always has new sources of the first fuel supply from energy efficiency. With a long history of energy efficiency policies and improvement efforts, by 1990, Japan was already a relatively efficient economy, with comparatively fewer opportunities to improve energy efficiency. However, energy efficiency has been the main contributor to the reduction in actual energy use since 2000 (IEA 2013b). From 2001 to 2012, Japan's energy intensity has been decreasing from 0.14 to approximately 0.11 tonnes of oil equivalent (toe) per US$1,000 (2005 constant price), which was well below the world average of 0.187. In addition, per capita energy use has also declined since 2004, reaching 3.5 toe per person, also below the IEA average of 4.5. However, in 2012, Japan could still save its consumers US$3 billion in energy bill reductions, with more efficient lighting, vehicles, and appliances (IEA 2013b) (Fig. 2.2).

Other countries have also gained the first fuel supply from energy efficiency improvement and energy intensity reductions. According to the IEA (2013a), in 2012, the USA made the biggest relative improvement in energy intensity as a result of efficiency gains in industry and services, together with fuel switching in power generation to natural gas. The second biggest improvement was in Russia due primarily to lower energy use per unit of output in industry and services. Russia was closely followed by China, where efficiency improvements in industry and higher output from hydropower and other renewables led to a 4 % improvement in energy intensity in 2012. From being four times higher than the global average in 1990, China's energy intensity is now less than twice the global average. In the Middle East, in contrast to other regions, energy intensity increased in 2012, mainly due to increased activity in energy-intensive industry (e.g., petrochemicals) and rapid energy demand growth in buildings and transport. Energy intensity across almost all regions improved over the last two decades. Between 1990 and 2000,

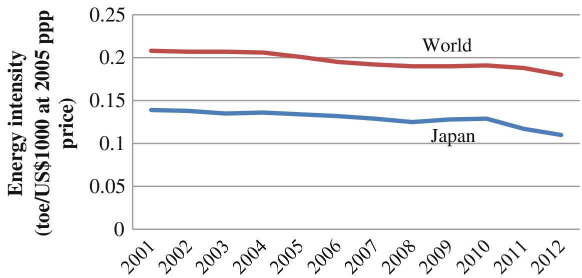


Fig. 2.2 Energy intensities of Japan and the world. *Source* Authors developed chart from data of Yang (2013) and IEA (2013b)

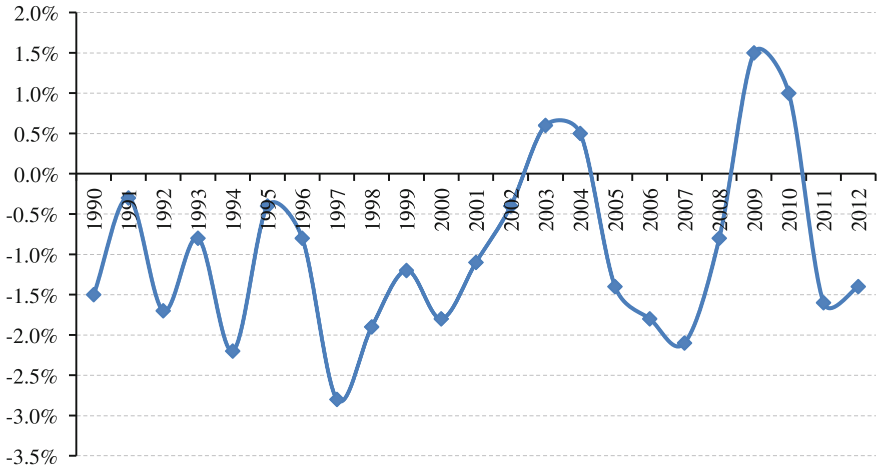


Fig. 2.3 Annual average change in global primary energy intensity, 1990–2012. *Source* Authors developed chart from self-collected data and calculations

global energy intensity (disregarding changes in the regional makeup of regional GDP) improved by 1.4 % per year and 1.8 % per year over the period from 2000 to 2012 (Fig. 2.3).

2.4 The Future Potential of the First Fuel

The IEA (2012) showed that if new energy efficiency policies and technologies had been put into practice and operation, the 11 IEA first member countries would have been able to achieve much more savings. Figure 2.3 shows the percentages of energy savings achieved in industry, transport, power generation, and buildings against the full potential of energy savings with the implementation of the new government policies and new energy-efficient technologies.

In OECD countries, energy efficiency policies and technologies would help generate the first fuel about 2.2 billion toe to meet an average of 20 % of total final energy consumption in 2030 in five major sectors, namely buildings, equipment, lighting, transport, and industry (Fig. 2.4). If other sectors are considered, the saving potential would be more than 20 %. The potential for generating the first fuel from energy efficiency in developing countries could be higher than IEA/OECD countries because of the widespread use of inefficient energy technologies. There is a huge economic opportunity to develop the first fuel globally, and the world is not even close to tapping it yet.

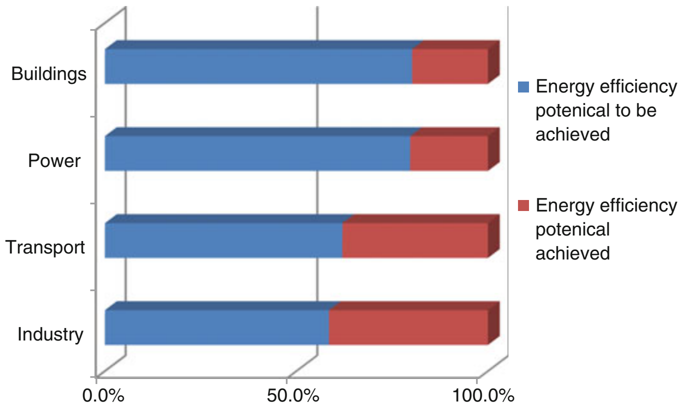


Fig. 2.4 Proportion of economic energy efficiency potential 2012–2035. *Source* Authors developed chart from data of the IEA and others

2.5 Challenge to the First Fuel

The "first fuel" has not been widely accepted in the world due to a large number of challenges and barriers. The major challenge is fossil fuel production and consumption subsidies, which distort energy efficiency markets in many countries, pushing up energy use and emissions, and engendering large economic costs. Fossil fuel consumption subsidies worldwide were estimated to have totaled US$544 billion in 2012 (IEA 2013a). Investment in energy efficiency was approximately US $300 billion, although it is cheaper and more effective than any other energy resources (renewables and fossil fuels) in terms of meeting the increasing world energy demand and mitigating global environment pollution. As such, the total investment in energy efficiency was still less than two-thirds of the level of fossil fuel subsidies in the world in 2012. Where there are more energy subsidies, there are less energy efficiency investments. Besides this major challenge, there are other barriers to energy efficiency as the first fuel. Chap. 6, after the methodology chapter, presents details of these barriers and approaches to removing them.

2.6 Applications of Energy Efficiency as Fuels

Energy efficiency resource standards (EERS) in the USA established specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs. An EERS can apply to either electricity or natural gas utilities, or both, depending on the state, and can be adopted through either legislation or regulation. An EERS is similar in concept to a renewable energy standard (RES) or renewable portfolio standard (RPS). While an

RES requires that electric utilities generate a certain percentage of electricity from renewable sources, an EERS requires that they achieve a percentage reduction in energy sales from energy efficiency measures. In terms of result impact to the country, both RES and EERS perform as fuel supplies to the country.

As of July 2013, 25 states in the USA have fully funded policies in place to establish specific energy-saving targets that utilities or non-utility program administrators must meet through customer energy efficiency programs. The strongest EERS requirements exist in Massachusetts and Vermont, which require almost 2.5 % savings annually.

A federal EERS would complement existing state-level energy efficiency standards by setting a national goal for energy savings that would be implemented over a specific period of time. The American Clean Energy Security Act of 2009 proposed a 5 % efficiency target, with an option for governors to petition that an additional 3 % of the reductions come from efficiency in their states. Because business-as-usual projections for efficiency savings in 2020 are already close to 5 % of nationwide electricity sales, a 10 % requirement as a more appropriate target would have a significant and positive impact on the US economy.

At both the federal and state levels, an EERS is a critical policy that lays the foundation for sustained investment in energy efficiency to harness the first fuel. The long-term goals associated with an EERS send a clear signal to market actors about the importance of energy efficiency in utility program planning, creating a level of certainty that encourages large-scale investment in a cost-effective manner to use the first fuel to power economy.

2.7 Summary

Energy efficiency as the largest share of fuel has significantly contributed to meeting energy demand in the first 11 IEA member countries over the past 40 years. Since 1974, energy efficiency in these 11 countries helped to avoid burning 1.5 billion tonnes of oil equivalent. Between 2005 and 2010, these 11 countries achieved saving US$420 billion in importing energy from the international market. Without these energy efficiency measures implemented, consumers in these 11 countries would have paid two-thirds more than they paid for their energy bills during 2010–2013. However, for many years, energy efficiency was not treated as the first fuel in energy and power expansion planning and was referred as a “hidden fuel.” Today, this situation is changing, and energy efficiency has been treated by more and more countries as “the first fuel.”

The first fuel will never run out due to limited fossil energy resources; government new policies on energy and climate change; and incoming new energy-efficient technologies, products, and equipment in the market. The actual potential of energy efficiency as a fuel is much greater than what the world has harnessed over the past 40 years. In OECD countries alone, energy efficiency policies and technologies would help generate the first fuel about 2.2 billion toe to meet an average of 20 % of final energy consumption in 2030 in five major sectors, namely buildings, equipment, lighting, transport, and industry.

There are many barriers to harnessing the first fuel. The major barrier is the subsidy for fossil fuel production and consumption. Fossil fuel consumption subsidies worldwide were estimated approximately 30 % more than total investments in the first fuel worldwide, which significantly distorted energy efficiency market.

Governments can use policy tools to facilitate harnessing the first fuel. In the USA, for example, the government established EERS for utilities or non-utility program administrators to follow and comply. An EERS is a critical policy that lays the foundation for sustained investment in energy efficiency, send a clear signal to energy market players about the importance of energy efficiency in utility program planning, and encourage large-scale investments in a cost-effective manner in energy efficiency.

References

IEA—International Energy Agency (2007) Lights Labour's Lost. OECD, Paris. https://www.iea.org/publications/freepublications/publication/name,3644,en.html

IEA—International Energy Agency (2012) World energy outlook 2012. OECD/IEA, International Energy Agency, Paris

IEA—International Energy Agency (2013a) Energy efficiency 2013: market report, market trends and medium-term prospects

IEA—International Energy Agency (2013b) From hidden fuel to world's first fuel? http://www.iea.org/newsroomandevents/pressreleases/2013/october/name-43788-en.html Cited 25 July 2014

Jollands N, Waide P, Ellis M, Onoda T, Laustsen J, Tanaka K, T'Serclaes P, Barnsley I, Bradley R, Meier A (2010) The 25 IEA energy efficiency policy recommendations to the G8 Gleneagles plan of action. Energy Policy 38(11):6409–6418

Lovins A (1976) The road not taken? energy strategy: friends of the earth's not man apart. Spec Reprint Issue 6(20):1977

Meadows D et al (1972) Limits to growth. Universe Books, New York

Yang M (2013) Closing the gap: GEF experiences in global energy efficiency. Springer, Berlin. ISBN: 978-1-4471-4516-5. http://www.springer.com/engineering/energy+technology/book/978-1-4471-4515-8

Chapter 3
Energy Efficiency Becomes First Tool for Climate Change Mitigation

Abstract In November 2014, the US and the Chinese governments announced their carbon emission reduction targets by 2030. The objective of this chapter was to quantitatively project the two countries' carbon emissions. A top-down approach is used to analyze the relationship between the Chinese economic development and energy demand, and identify potentials of energy savings and carbon emission reduction in China. A simple time series approach is utilized to project carbon emission reduction in the USA. The predictions drawn from the analysis of this chapter indicate that both China and the USA need to use energy efficiency as a first tool to achieve their carbon emission reduction goals.

3.1 Introduction

During the Beijing 2014 APEC meeting on November 13, 2014, the USA and China jointly announced their targets to mitigate greenhouse gas (GHG) emissions. US President Barack Obama publicized a new target to cut net US GHG emissions by 26–28 % below that in 2005 by 2025. At the same time, Chinese President Xi Jinping broadcasted that China will peak its gross CO_2 emissions and will increase non-fossil fuel share of all energy to approximately 20 % by 2030. Being the largest GHG emitting countries, the USA and China account for over 42 % of global GHG emissions (IEA 2013). If any of the two great countries (G2) does not want to address climate change, global climate change negotiation will not achieve any substantial commitment for mitigation targets. Now, these G2 have highlighted their critical roles in addressing climate change. The USA will submit its 2025 target to the United Nations Framework Convention on Climate Change as an "Intended Nationally Determined Contribution" no later than the first quarter of 2015; China agreed to peak its CO_2 emissions by means of energy efficiency and non-fossil energy investments.

Obama's announcement was supported by the US energy policy to use energy efficiency as the first tool in the next 10 years. The new US goal will double the

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_3

pace of carbon emission reduction from 1.2 % per year on average during the 2005–2020 period to 2.3–2.8 % per year on average between 2020 and 2025 (U.S. EAP 2014a). This ambitious target is grounded in intensive analysis of cost-effective carbon emission reductions achievable under the existing US EPA's Clean Air Act and will keep the USA on the right trajectory to achieve deep economy-wide reductions of GHG emissions by 80 % below the 1990 level by 2050. In its proposed rule on June 18, 2014, the US EPA considered the following existing policies and programs to be conducted for its decarbonization target: (1) market-based emission limits, (2) GHG performance standards, (3) utility planning approaches, (4) renewable portfolio standards, (5) demand-side energy efficiency programs, and (6) energy efficiency resource standards. Five out of these policies and programs are related to energy efficiency.

Similarly, Xi Jinping's announcement was based on the assumption that energy efficiency will continue serving as the first fuel to power the Chinese economy. From 1980 to 2005, China had remarkably accomplished more than 60 % reduction in energy intensity (energy consumption per unit of GDP). Afterward, the Chinese government pledged to cut China's carbon intensity by 40–45 % at the 2005 level by 2020, and energy efficiency has been used as a tool to achieve this pledged goal. In its 11th Five-Year Plan (2006–2010), the government has set a mandatory target to cut energy intensity by 20 %, and actually achieved 19.1 %. During the 12th Five-Year Plan (2011–2015), the government continued setting a target of 16 % reduction of China's energy intensity by 2015. In the meantime, the government is in the process of developing China's 13th Five-Year Plan (2016–2020). To guide this process, President Xi Jinping called for "energy revolution" in China's energy sector which covers dramatic changes in energy consumption, energy supply, institutional reform, technology innovation, and international cooperation. Following Xi's initiative, the government will use multiple measures in reducing carbon emissions in its 13th Five-Year Plan, including new targets for energy intensity reduction, increased use of market-based mechanisms, and mandatory caps of total energy consumption for cities, provinces, and major industrial entities. The following sections present analyses and results of the two countries' GHG emission targets and highlight energy efficiency as the first tool to achieve these targets.

3.2 Analysis of GHG Reduction Target for China

There are two main drivers of China's high growth of GHG emissions: (1) fast and long-lasting economic development and (2) continued inefficient use of energy. These two drivers are highly related to the Chines government economic development and energy policies. There are also two drivers for China's GHG emission reduction: (1) using energy efficiency as the first fuel to power economy and (2) enlarging investments in non-fossil energy, namely renewable energy and nuclear energy. The analysis of China's GHG emission target is therefore based on the country's economic development, energy efficiency improvement, and non-fossil energy investment.

3.2.1 China's Dream and Economic Development Outlook

The rapid rise of China as a major economic power within three decades is often described as one of the greatest economic success stories in modern times. From 1979 (when economic reforms began) to 2011, China's real GDP grew at an average annual rate of nearly 10 %. In this period, GDP grew 19-fold in real terms; real per capita GDP increased 14-fold; and over 500 million people were raised out of extreme poverty. China is now the world's second largest economy, and some analysts predict that it could become the largest within a few years (Fig. 3.1).

Historical data also show that China's GDP growth rates changed in a cyclical curve with 9–10 years in each period (Fig. 3.2). The last valley point was in 1998, while the peak point appeared in 2003. Figure 3.2 also presents trend curve of the historical GDP growth rates. It seems that China passed the highest GDP growth rate at the beginning of the twenty-first century. It is unlikely that China's GDP will sustainably grow again at a rate of more than 10 % per annum for a period of several years. On the basis of such historical trend, the authors projected that the China's GDP growth rate will continue decline slightly in the forthcoming three years down to approximately 6.5 %; then, it will raise again gradually up to 8 % by 2030. To be conservative, this analysis assumes that China's GDP growth rate will be between 6 and 8 % during the next one and a half decades.

The above projection of China's economic development growth rate also complies with the current economic and social development policy of the country. Just after becoming Chinese president in late 2012, Mr. Xi Jinping announced "The China Dream." He said that the dream is great rejuvenation of the Chinese nation.

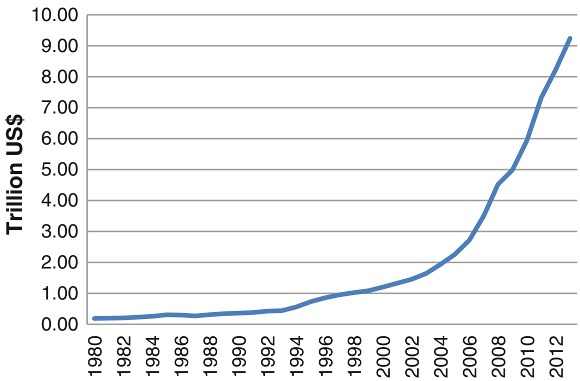


Fig. 3.1 China's GDP in market price. *Source* World Bank (2014a)

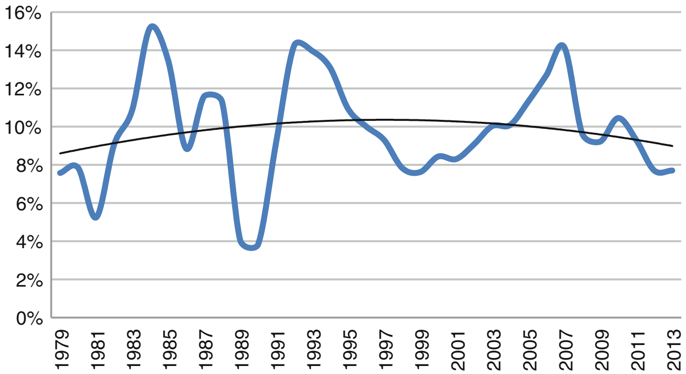
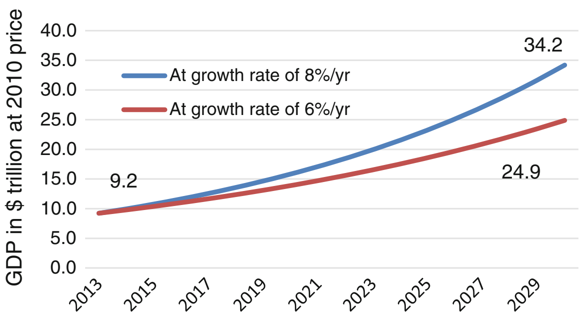


Fig. 3.2 China's GDP growth rate

Xi's China Dream is described as achieving the "Two 100s." The first "100" means that by 2021 which will be the 100th anniversary of the Chinese Communist Party, China should become a country with "moderately well-off society." The second "100" means that by 2049 which is the 100th anniversary of the founding of the People's Republic China, the country should achieve its goal of modernization, becoming a fully developed country in the world (Baidu 2014). To achieve these two targets, the national GDP must keep growing at a rate between 6 and 8 % per annum from 2015 to 2030.

China will likely triple its GDP from 2015 to 2030 if its GDP is growing at an average rate somewhere between 6 and 8 %. In 2013, China's GDP reached US $9.24 trillion at 2010 constant price. By 2030, with an average growth rate of 8 % per annum, China's GDP will reach approximately US$35 trillion, which is 3.5-fold as its 2013 level. With an average growth rate of 6 % per annum, China's GDP will be US$25 trillion in 2030, which is 2.5-fold as its 2013 level (see Fig. 3.3).

Fig. 3.3 China's GDP projection



3.2.2 China's Carbon Emissions Outlook

3.2.2.1 China's Historical Carbon Intensity

China has significantly reduced its carbon intensity over the past 30 years. From 1979 to 2012, the country's carbon intensity had been reduced from 7.6 kg CO_2/US$ in 1979 to 1.8 kg CO_2/US$ in 2012. The major reduction was achieved during the period of 1979–2002 by means of energy efficiency and renewable energy investments. From 2002 to 2012, this figure did not change very much in the range of 1.8–2.4 kg CO_2/US$ as China invested significantly in heavy industries and infrastructure (Fig. 3.4), both of which were energy intensive. This section describes China's carbon emissions during the forthcoming 15 years with four scenarios: (1) business as usual, (2) using energy efficiency as the first fuel, (3) enlarging investments in non-fossil fuel technologies, and (4) using energy efficiency as the first fuel and enlarging investments in non-fossil fuel technologies.

3.2.2.2 Business as Usual (Scenario 1)

In the business as usual scenario, China is assumed to develop its GDP at a rate of between 6 and 8 % per annum, and the country will not have additional policies to promote energy efficiency and non-fossil energy. In other words, China will triple its GDP but keep its carbon intensity unchanged at the level of 2013. As a result, China's total CO_2 emissions will reach 36.6 billion tonnes of CO_2eq (Fig. 3.5).

3.2.2.3 Using Energy Efficiency as the First Fuel to Reduce Carbon (Scenario 2)

China's Historical Energy Intensities

Similar to carbon intensity reduction trend, China's energy intensity has been declining significantly. From 1979 to 2012, energy intensity, calculated in tonnes of

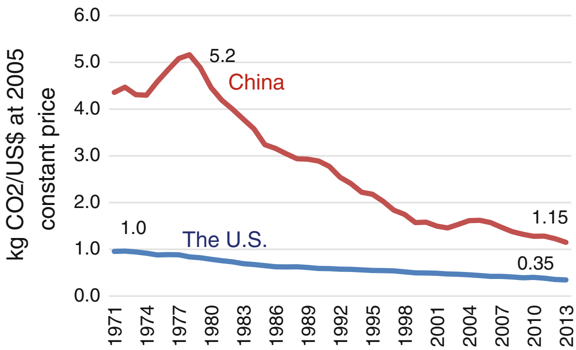


Fig. 3.4 Carbon intensity in China and the USA

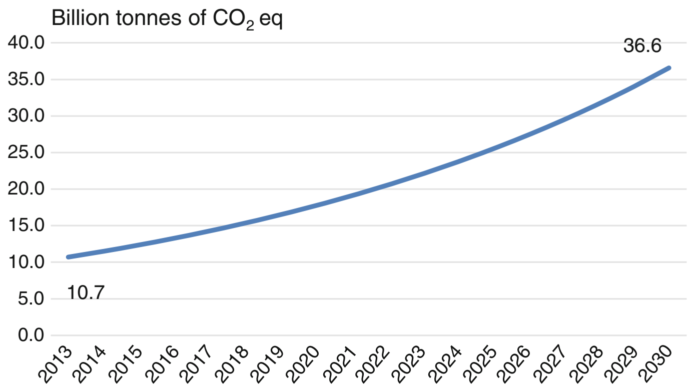


Fig. 3.5 China's carbon emissions under scenario 1

oil equivalent per $1,000 GDP output in 2011 constant price, was reduced from 0.52 to 0.20 (or by 61.5 %) in China, while this figure was reduced from 0.21 to 0.14 (33 %) in the USA (see Fig. 3.6). In 2012, energy intensity of China was 42.9 % higher than that of the USA. There is a great potential for China to improve energy efficiency and reduce energy intensity. It seems that the figure of 0.2 toe/$1,000 was special in energy intensity for the two countries. The USA recorded this figure in 1992, 1993, and 1994. After 17 years, China also recorded this figure in 2010 and 2011. In the USA, it took approximately 15 years, from 1996 to 2011, to reduce energy intensity from 0.20 to 0.15 toe/$1,000. The authors assume that with appropriate energy efficiency policies, China will likely follow the USA in energy intensity reduction and be able to cut its energy intensity from 0.2 in 2015 to 0.15 toe/$1,000 in 2030.

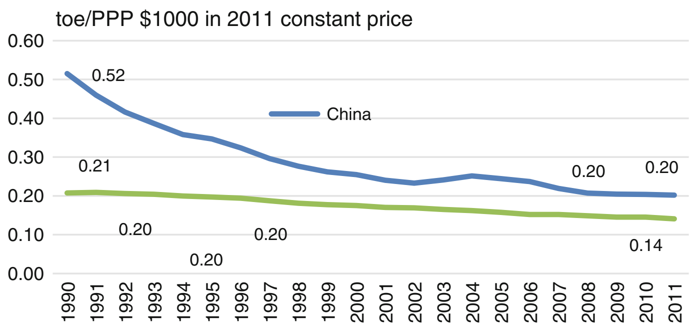


Fig. 3.6 Energy intensity in the USA and China. *Source* World Bank (2014b)

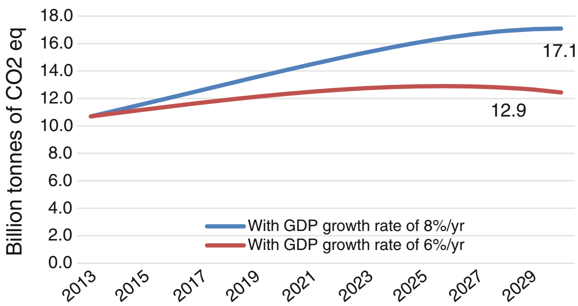


Fig. 3.7 China's carbon emission with 0.5 kg CO_2/$ of EI in 2030

Carbon Intensity Reduction with Energy Efficiency as the First Fuel

Comparing Figs. 3.6 and 3.7, one can see that China's carbon intensity and energy intensity have the same changing pattern in the history, implying that they are highly correlated. Reducing energy intensity has direct impact on reducing carbon intensity. Thus, the authors assume that Chinese energy efficiency policies will have direct impact on carbon emission reductions in China, and that with appropriate energy efficiency policies, China's carbon intensity reduction path could follow that of the USA.

Carbon intensity in the USA has been constantly decreasing from 1 kg CO_2/US$ in 1979 to 0.4 kg CO_2/US$ in 2012. China's carbon intensity from 2014 to 2030 will likely be in a range of 1.2 kg CO_2/US$ in 2015 to 0.5 kg CO_2/US$ in 2030. This assumption implies that energy efficiency will be the first fuel in China to reduce approximately 47 g CO_2/US$ of GDP per year! Overall, China's carbon intensity would be reduced from 1.2 kg CO_2/US$ in 2015 to 0.5 kg CO_2/US$ in 2030. Multiplying this figure by China's projected GDP gives a picture of China's CO_2 emissions in the next 15 years.

As shown in Fig. 3.7, China's carbon emission will pick between 2027 and 2029 depending on implementation of its economic development policy and energy efficiency policy. If the country favors high economic development with average GDP growth rate at 8 % per annum, carbon emission will peak at 17.1 billion tonnes of CO_2eq in 2029. If the country slows down its economic development with an average GDP growth rate of 6 % per annum, the country's carbon emissions will peak at 12.9 billion tonnes of CO_2eq in 2027. It should be stressed again that energy efficiency must be the first fuel to cut the country's energy intensity by 47 g CO_2/US$ of GDP per year.

3.2.2.4 Enlarging Investments in Non-fossil Fuel Technologies (Scenario 3)

Scenario 3 only accounts the impact of non-fossil energy development on carbon emission reductions. In 2013, when China's non-fossil energy production reached

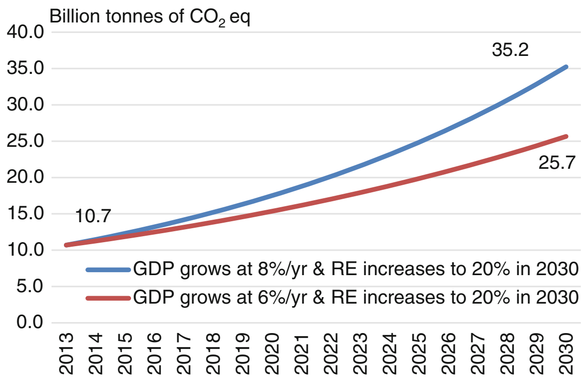


Fig. 3.8 China's carbon emission with 20 % of non-fossil energy in 2030

10 % of the country's total energy production, China's carbon intensity was 1.16 kg CO_2/\$. It means that 90 % of China's fossil energy contributed to 1.16 kg CO_2/\$. In 2030, if China achieves its target of using 20 % non-fossil fuel in its energy mix, the country's fossil energy will reach 80 %. The contribution of non-fossil energy to carbon intensity reduction will be reduced from 1.16 kg CO_2/\$ in 2013 to 1.03 kg CO_2/\$ in 2030 without accounting energy efficiency as the first fuel.

With an assumption that the amount of 0.13 kg CO_2/\$ (1.16–1.03) is reduced linearly from 2013 to 2030, the authors calculated carbon emissions of China under scenario 3 by multiplying the carbon intensities with projected GDP of China from 2013 to 2030. Figure 3.8 shows the results.

China's carbon emissions would not likely peak if the country only enlarges its non-fossil energy share to 20 % by 2030 without using energy efficiency as the first fuel. The reason is that China will likely more than double its total energy consumption in the next 15 years, while carbon emission reductions by means of enlarged non-fossil energy supply from 10 to 20 % of the total energy supply cannot off set the carbon emission growth due to the massive net increase of fossil energy consumption. By 2030, China's total carbon emissions will reach 35.2 and 27.5 billion tonnes of CO_2eq at 8 and 6 % GDP growth rates under scenario 3 (Fig. 3.8).

3.2.2.5 Using Energy Efficiency as the First Fuel and Enlarging Non-fossil Fuel to 20 % (Scenario 4)

Fortunately, scenario 3 will not likely come true, since China will use both energy efficiency as the first fuel and enlarge non-fossil fuel share at the same time. Scenario 4 integrates both of these two efforts of carbon emission reduction, and Fig. 3.9 shows the results.

Under Scenario 4, the country's carbon emission will peak between 2024 and 2028 depending on the growth rate of the country's GDP. If the average GDP growth rate is 8 % per annum, carbon emissions will peak at 15.5 billion tonnes of CO_2eq in 2028. If the GDP is growing at 6 % per annum, carbon emissions will peak at 12.2 billion tonnes of CO_2eq in 2024.

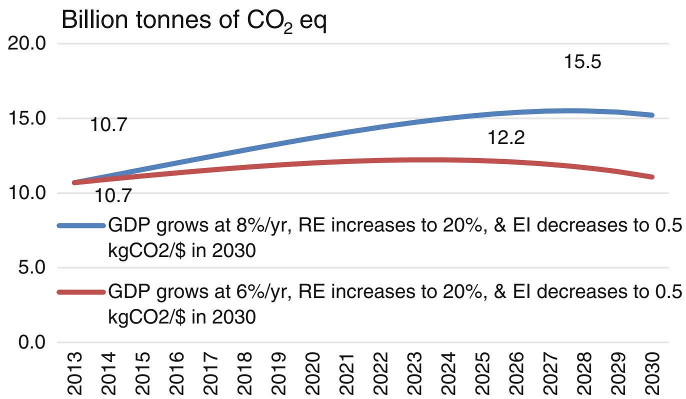


Fig. 3.9 China's carbon emission with 20 % of non-fossil energy (RE) and 0.5 kg CO_2/$ of energy intensity in 2030. *Source* World Bank (2014b)

3.3 Analysis of GHG Reduction Target for the USA

Since 2007, carbon emissions in the USA have been decreasing. Major drivers of GHG emission reductions are related to reduction of air pollutions in the US Analysis on the USA. Clean Air Act will help understand GHG emission reductions in the past and in the future. The Clean Air Act and its related activities are related to energy efficiency in different sectors, including transport, commerce, households, and agriculture. The last but not least sector for clean air and GHG emission reduction should be the power generation sector.

3.3.1 US EPA's Clean Air Act and Climate Change Mitigation Policies

The Clean Air Act is a US federal law designed to control air pollution on a national level. It requires the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the public from airborne contaminants known to be hazardous to human health. The development of the US Clean Air Act can be traced back from the 1950s. The 1955 Air Pollution Control Act was the first US federal legislation that pertained to air pollution; it also provided funds for federal government research of air pollution. The first federal legislation to actually pertain to controlling "air pollution" was the Clean Air Act of 1963. The 1963 act accomplished this by establishing a federal program within the US Public Health Service and authorized research into techniques for monitoring and controlling air pollution. In 1967, the Air Quality Act enabled the federal government to increase its activities to investigate enforcing interstate air pollution transport, and, for the first time, to perform far-reaching ambient monitoring studies and stationary source inspections. The 1967 act also authorized expanded studies of air pollutant emission inventories, ambient monitoring techniques, and control techniques (U.S. EPA 2014b).

Major amendments to the law, requiring regulatory controls for air pollution, passed in 1970, 1977, and 1990. The 1970 amendments greatly expanded the federal mandate, requiring comprehensive federal and state regulations for both stationary (industrial) pollution sources and mobile sources. It also significantly expanded federal enforcement. Also, the US EPA was established on December 2, 1970, for the purpose of consolidating pertinent federal research, monitoring, standard-setting, and enforcement activities into one agency that ensures environmental protection (U.S. EPA 2014c).

The 1990 amendments addressed acid rain, ozone depletion, and toxic air pollution, established a national permits program for stationary sources, and increased enforcement authority. The amendments also established new auto gasoline reformulation requirements, set Reid vapor pressure (RVP) standards to control evaporative emissions from gasoline, and mandated new gasoline formulations sold from May to September each year in many states.

Since the start of Obama's administration, the US EPA has worked more actively on mitigating GHG emissions. Significant milestones include the following:

- In December 2009, the US EPA found that GHGs are danger to human health and welfare;
- In April 2010, the EPA issued GHG Emissions Performance Standard (EPS) for cars and light trucks for the period of 2012–2016;
- On November 10, 2010, the US EPA made available important resources and guidance to assist state and local permitting authorities as they implement their Clean Air Act permitting programs for greenhouse gas (GHG) emissions.
- In September 2011, the EPA issued GHG EPS for medium and heavy trucks for the period of 2014–2018;
- In August 2012, the US EAP issued GHG EPS for cars and light trucks for the period of 2017–2025;
- In June 2013, President Obama directed the US EPA to reduce carbon pollution from power plants as part of a Climate Action Plan;
- In February 2014, President Obama directed EPA to extend EPS for medium and heavy trucks to post-2018 period (final by March 2015);
- In the first week of June 2014, the US EPA announced a proposal that required reductions in CO_2 emissions from existing fossil-fueled electric power plants. The proposal includes emission rate targets for each state, measured as pounds of CO_2 emissions per megawatt-hour of covered generation, as well as guidelines for the development, submission, and implementation of state plans. The emission rate targets vary significantly across individual states, reflecting the application of a series of common building blocks to states with widely different starting points in their respective electricity markets.

- In November 2014, President Barack Obama publicized the target to cut net GHG emissions of the US by 26–28 % below the level of that in 2005 by the year 2025 with major emission reduction sources from the US power generation and transport sectors.

There is still uncertainty for the USA to achieve this goal since the US Congress and Supreme Court do not support the President and the US EPA. In March 2011, the Republicans submitted a bill to the US congress that would prohibit the US EPA from regulating greenhouse gases as pollutants. On June 23, 2014, the US Supreme Court issued its decision in Utility Air Regulatory Group v. EPA (No. 12-1146). The Court said that the US EPA may not treat GHG as an air pollutant for purposes of determining whether a source is a major source required to obtain Prevention of Significant Deterioration (PSD) permits (or Title V Permit). As of December 2014, the US EPA had been evaluating the implications of the Court's decision and awaiting further action by the US Court.

3.3.2 GHG Emission Projection in the USA

In 2012, power generation (32 %) and transportation (28 %) were the largest two sectors in GHG reduction in the USA, accounting a total of 60 % GHG emissions in the country (U.S. EPA 2014c). Other GHG emissions in the USA included industry (20 %), agriculture (10 %), and commerce and household (10 %) (Fig. 3.10). Since the US EAP has well regulated the transportation sector, GHG emission reduction from the power generation sector will become a key factor in the USA to achieve Obama's 2025 GHG emission reduction target.

In power generation, using coal as primary energy is generally more carbon intensive than using natural gas or petroleum. In 2012 in the USA, coal accounted for

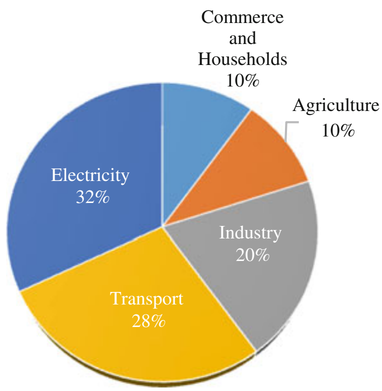


Fig. 3.10 Total U.S. GHG emissions by economic sector in 2012. *Data Source* U.S. EPA (2014e)

approximately 75 % of carbon emissions from the power sector, but coal-fired power plants only contributed to approximately 39 % of the electricity generation in the country. The other 61 % of power was generated using natural gas (29 %), oil (less than 1 %), nuclear (less than 20 %), and renewable sources (12 %) (U.S. EPA 2014d). If all coal-fired power plants are converted into non-coal-fired plants by 2025 with the same mixed power generation technologies as in 2012, the USA will be able to mitigate 1,233 million tonnes of CO_2eq, (61 % of the total target between 2005 and 2025) without taking into account efficiency improvement for the existing power plants. The second potential of carbon emission reduction in the power generation sector is to convert conventional coal power plants (with efficiency of 35 %) into gas-combined cycle power plants (with efficiency of 50 %) or co-generation power plants (with efficiency of 95 %). Then, the USA will be able to save 260 million tonnes of CO_2eq by using gas-combined technologies, or 1,039 million tonnes of CO_2eq (51 % of the total target between 2005 and 2025) by using co-generation technologies. To sum, the USA will be able to achieve its 2025 GHG emission reduction target by technology advancement and energy efficiency improvement in its power sector. From 2025 to 2050, the USA needs to continue energy efficiency investments and renewable energy development to achieve its 2050 GHG emission target, namely 80 % lower than the level in 1990. Figure 3.11 shows carbon emission trend in the USA from 1990 to 2012 and presents GHG emissions from 2013 to 2025 and from 2025 to 2050 according to the pledge of the US government.

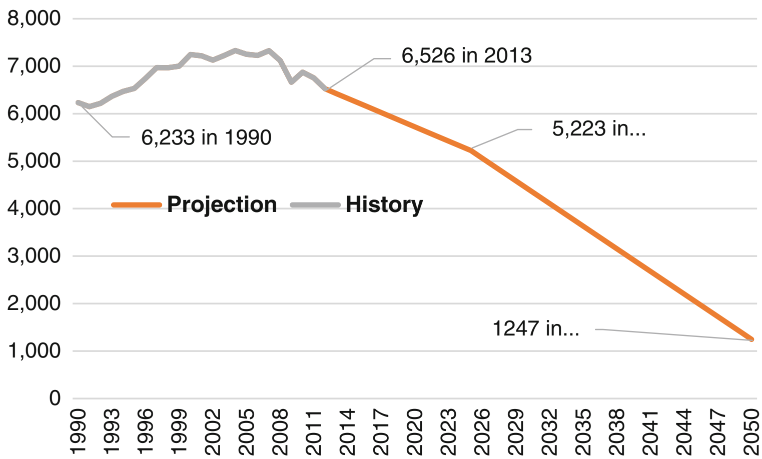


Fig. 3.11 Carbon emissions in the U.S. (million tonnes of CO_2eq). *Sources* Author calculated from data of the U.S. EPA and the IEA

3.4 Conclusions

Using historical economic development and energy policy data and empiric analysis methodology, this chapter tries to project GHG emission reduction figures for the USA and China by 2025 and 2030. The analysis shows that China will likely peak its GHG emissions in 2028 at 15.5 billion tonnes of CO_2eq under a high economic development scenario, or in 2024 at 12.2 billion tonnes of CO_2eq under a moderate rate of the economic development scenario, if the country uses energy efficiency as the first fuel and enlarges non-fossil fuel to 20 % of its total energy supply. Without using energy efficiency as the first fuel, it would be impossible for China to peak its GHG emissions before 2030.

In the USA, carbon emissions have been decreasing since 2007; this trend will continue if the US Supreme Court and the US government accept the fact that GHG emissions will affect human health and welfare. With the continued regulation effort of the US EPA on power generation, the USA will reduce its total GHG emissions down to 5.2 billion tonnes of CO_2eq by 2025, or 28 % lower than the level of 2005. This carbon emission reduction will be mainly contributed from power generation sector with replacement of coal-fired-power plants by gas-combined cycle technologies and co-generation technologies. After 2025, the USA needs to continue making its effort in energy efficiency investment and renewable energy investment to achieve its pledged target of GHG emission reduction in 2050.

From 2015 to 2024, even with its best energy efficiency and non-carbon energy policy and technologies, China will continue increasing its GHG emissions. The net increased GHG emission capacity in this period will be more than the total GHG emission capacity of the USA. Without energy efficiency policy and technologies, neither of the two countries would be able to achieve their climate change mitigation targets.

References

Baidu (2014) Chinese dream: Xi proposed guideline. http://baike.baidu.com/subview/1817221/9342599.htm. Cited on 26 Nov 2014

IEA—International Energy Agency (2013) CO_2 emissions from fuel combustion highlights 2013, Paris

U.S. EPA (2014a) Sources of greenhouse gas emissions. http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html. Cited on 16 Nov 2014

U.S. EPA (2014b) History of the clean air act. http://www.epa.gov/air/caa/amendments.html. Cited on 18 Dec 2014

U.S. EPA (2014c) Carbon pollution emission guidelines for existing stationary sources: electric utility generating units. A Proposed Rule by the Environmental Protection Agency on 18 June 2014. http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule

U.S. EPA (2014d) Sources of greenhouse gas emissions. http://www.epa.gov/climatechange/ghgemissions/sources/electricity.html. Cited on 18 Dec 2014

World Bank (2014a) Catalog sources world development indicators. http://data.worldbank.org/indicator/NY.GDP.MKTP.CD. Cited on 22 Dec 2014

World Bank (2014b) World development indicators. http://data.worldbank.org/country/china and http://data.worldbank.org/country/us

Chapter 4
Market Barriers to Energy Efficiency

Abstract Market barriers to energy efficiency come from various aspects including social psychology, organizational theory, system perspective, and economic concepts. Widely covering these aspects, this book classifies 11 barriers to energy efficiency investments in the energy market. These barriers include fossil energy subsidies in the energy market, high transaction costs for small- and medium-sized energy efficiency project investment, distorted market for energy efficiency investments, high risk for local banks to release low-interest loans to small- and medium-sized enterprises, and lack of capacity to develop and implement energy efficiency projects in developing countries. Fortunately, these barriers can be unlocked by various proven measures. These measures include, but not limited to, implementing government energy pricing reforms, using program approach to cutting down transaction costs for small projects, creating transparent and competitive energy markets through effective government policies and regulations, lowering interest rates of bank loans by establishing de-risk funds at local banks, and building capacities for developing countries.

4.1 Introduction

The concept of market barriers can be approached from many perspectives, including social psychology (Palmer 2009), organizational theory (Montalvo 2008; Sorrell et al. 2000), and system perspective (Foxon 2003), but most studies use economic concepts, including transaction cost and behavioral economics to define energy efficiency barriers. In this book, a market barrier to energy efficiency is defined as "*a postulated mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient*." (Sorrell et al. 2004), since this definition is directly related to energy efficiency.

Research and discussions on energy efficiency barriers started in the late 1970s and the early 1980s. Blumstein et al. (1980) presented an analysis of the causes for the apparent discrepancies between energy efficiency investment opportunities and

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_4

actual investment activities systematically. While addressing economically rational responses to the energy crises, the article noted that energy conservation actions may be hindered by social and institutional barriers. Six barriers were initially listed to cause the energy efficiency gap between actual energy efficiency choices observed in current energy service markets and markets as predicted/described in economic theory. Golove and Eto (1996) also identified six market barriers to energy efficiency investments: (1) misplaced incentives or subsidies, (2) lack of access to finance, (3) flaws in market structure, (4) mispricing imposed by regulation, (5) decision influenced by custom, and (6) lack of information. The IEA (2007) argued that market barriers leading to energy efficiency gaps occur under three conditions: (1) when barriers in capital markets inhibit the purchase of energy-efficient technologies, (2) when energy-efficient markets are incomplete, and (3) when energy costs are a low priority relative to other factors. More recently, with a focus on industrial energy efficiency, Sorrell et al. (2004) also pointed out six barriers: (1) risk, (2) imperfect information, (3) hidden costs, (4) access to capital, (5) split incentives, and (6) bounded rationality. Different researchers, scholars, and energy efficiency practitioners have different views regarding energy efficiency barriers since they address different aspects of energy efficiency.

This book widely covers various aspects of energy efficiency including government policy and standards, markets, economics and finance, technologies, engineering, and energy system design and operations. Therefore, this book categorizes the major barriers to energy efficiency as follows: (1) worldwide subsidies to fossil energy, (2) high transaction costs, (3) invisibility of energy efficiency projects, (4) misplaced incentives, (5) lack of access to financing, (6) misplaced pricing imposed by regulation, (7) gold plating and inseparability of features, (8) externalities, (9) imperfect information, (10) customer inertia, and (11) lack of capacity.

4.2 Worldwide Subsidies to Fossil Energy

Energy subsidies are measures and practices that keep energy prices for energy producers and end users below marginal costs of clean energy production or consumption. Producer subsidies often arise when state-owned energy enterprises, power utility for example, are inefficient and have high costs of production because of non-payment or low payment of bills from government agencies and power distribution losses. The International Monetary Fund stated that worldwide post-tax subsidies, which are the sum of pre-tax and tax subsidies, amounted to US$1.9 trillion or 2.7 % of the total GDP of the world in 2012 (IMF 2013). Subsidies to fossil energy encourage excessive fossil energy production and consumption, which accelerates the depletion of natural resources. They also reduce the incentive for investment in energy efficiency. If the amount of US$1.9 trillion capital was invested annually in energy efficiency, the world could have closed the energy efficiency investment gap.

The group of 20 advanced and emerging market economies (G20) initially called for phasing out inefficient fossil fuel subsidies in all countries in 2009 and reaffirmed this again in 2012. Despite the global policy and strategy, many countries have had difficulty phasing out subsidies. When subsidy reform takes place, prices increase which often leads to widespread public complaints and protests. Governments are also often concerned that higher energy prices will contribute to a higher rate of inflation and adversely affect their competitiveness. Subsidy reform can also be complex when the purpose is to reduce inefficiencies and production costs. For example, in a public-owned power sector, utilities are used to government regulatory policy that guarantees their minimum return in operation. Reforming subsidy will force these power utilities to adapt new and changing electricity market, which may cause loss of revenue and loss of jobs to the utility companies. While there is no single recipe for successful subsidy reform, the IMF (2013) suggests the following to overcome the energy subsidy barrier:

1. a comprehensive energy sector reform plan with clear long-term objectives with an analysis of the impact of reforms;
2. transparent and extensive communication and consultation with stakeholders, including information on the size of subsidies and how they affect the government's budget;
3. price increases that are phased in over time;
4. improving the efficiency in state-owned enterprises to reduce producer subsidies;
5. measures to protect the poor through targeted cash or near-cash transfers or, if this option is not feasible, a focus on existing targeted programs that can be expanded quickly; and
6. institutional reforms that depoliticize energy pricing, such as the introduction of automatic pricing mechanisms.

4.3 High Transaction Costs

A transaction cost in an energy efficiency project is a cost that is necessary to move the project forward in a market. Transaction costs can be divided into four categories: (1) the cost of acquiring, assessing, and using information to determine whether the energy efficiency project can achieve its targets; (2) the cost of negotiation to come to an acceptable agreement with all project stakeholders to draw up an appropriate contract, etc.; (3) the cost of policy and enforcement to make sure all project stakeholders stick to the terms of the project contract, and to take appropriate actions; and (4) the premium cost to guarantee the participation of key stakeholders in the project. These costs may be very high for some energy efficiency project stakeholders. This is particularly true for customers of small businesses and individual households. For these customers, the hurdle rate, which is defined as the minimum acceptable rate of return on a capital investment project, is usually used in decision making. DeCanio (1993) found that hurdle rates established internally by small businesses and households for energy efficiency investments are higher than the capital costs to them. In other words, small businesses and households will not invest in energy efficiency technologies unless the internal rate of return for energy efficiency investments is higher than the cost of capital. Consequently, policy and financial incentives are necessary to provide additional incentives to attract capital investments in energy efficiency even if energy efficiency projects are financially viable. In addition, developing and investing in energy efficiency programs at the national level with the involvement of multi-provinces/states, multi-sectors, and multi-areas (e.g., policy development, technology transfer, and capacity building) will help reduce transaction costs for small businesses and individual households.

4.4 Invisibility of Energy Efficiency Projects

Energy efficiency technologies in a project are usually invisible because they are distributed in a large scope. For example, an energy efficiency lighting program may cover a country, or a region. The investment is small in terms of each piece of lamps or lighting fixtures; it could be difficult to quantify the benefits of the project. In contrast, investment in renewable energy technologies, such as a hydropower plant or a biomass-fired power plant, is more visible and centralized. Renewable energy investment is also relatively easier and cheaper to monitor, verify, and quantify benefits. To overcome this barrier, it is worthwhile to involve national media including TV programs and government campaigns such as annual energy efficiency week to demonstrate results or achievements of energy efficiency technologies in the country.

4.5 Misplaced Incentives

Misplaced, or split, incentives are transactions or exchanges where the economic benefits of energy savings do not accrue to the person who is trying to save energy. The terms have been used to describe certain classes of relationships, primarily in the real estate industry between landlords and tenants with respect to acquisition of energy-efficient equipment for rental properties. When the tenant is responsible for the energy/utility bills, it is in the landlord's interest to provide least-first-cost equipment rather than more efficient equipment for a given level of desired service. There is little or no incentive for the landlord to increase his or her own expense to acquire efficient equipment (such as efficient refrigerators, heaters, and light bulbs) because the landlord does not bear the burden of the operating costs and will not reap the benefits of reducing those costs. This misplaced incentive is believed to extend to the commercial sector in lighting and heating, ventilation, and air conditioning (HVAC) as well.

To overcome this energy efficiency barrier, government energy efficiency standards and codes for housing and rental leasing can help. High energy efficiency standards and codes will force landlords and the energy market to phase out inefficient equipment such as incandescent lamps regardless of who pays for the lamps. For the complexity and variety of commercial lease agreements, some contract clauses, which require both the landlord and the tenant to pay utility bills in a pre-negotiated way, may mitigate this barrier.

4.6 Lack of Access to Financing

The financing barrier, sometimes called the liquidity constraint, refers to significant restrictions on capital availability for potential borrowers or consumers. In a perfect competition market, all kinds of borrowers should access capital for their investment needs. In practice, however, some potential borrowers such as low-income individuals and small-business owners, are frequently lack of access to capital, which inhibits investments in energy efficiency by these consumers. The government can help remove this kind of barriers. For example, if a consumer wishes to purchase energy-efficient equipment, the local financial market should provide special loans for such investments with low interest rates, which can be realized by a government guarantee fund to reduce lenders' risks. The government may establish de-risk funds to reduce risks for commercial banks. For instance, if an energy service company plans to retrofit a building and make it energy efficient, local banks can provide loans with lower interest rate under the established government de-risk funds.

4.7 Regulatory Barrier

The regulation barrier referred to mispricing energy. These procedures and the cost structure of the industries typically result in different prices depending on whether they are set based on average costs (the regulated price) or marginal costs (the market price). Historically, the price of electricity as set by regulators was frequently below the marginal cost to produce the electricity. This mispricing was claimed to create an incentive to overconsume electricity relative to conservation or efficiency. If marginal costs of electricity production have dropped below prices as set administratively, the price of electricity may provide an incentive to overinvest in energy efficiency. The regulatory barrier can be removed by adjusting regulated energy prices. If independent energy producers do not have interest in bidding energy efficiency projects, the government regulatory agency needs to raise the regulated energy price, and vice versa.

4.8 Gold Plating and Inseparability of Features

The concept of "gold plating" in energy efficiency means that some equipments are frequently coupled with other costly features and are not available separately (Ruderman et al. 1987). As a result, buyers may be forced to purchase unnecessary/undesirable features that need energy to run or to make the equipment standby.

Inseparability of features refers to the necessary and integrated balance of energy efficiency with technologies. For any specific technology, there is always a limitation of trade-off between energy efficiency and other desirable features. For example, in designing and developing a car, developers and manufactures have to consider the trade-off between energy efficiency and safety because it is not possible with current technology to maintain or increase one while simultaneously increasing the other. Many customers prefer to buy a big and inefficient car, taking into account safety on roads, even if they know a light and efficient car will save a large amount of gasoline bills in the lifetime. Both gold plating and inseparability of features have become barriers to energy efficiency. Government policy and regulation can help overcome these barriers. For example, an energy policy may increase tax for energy-intensive cars which have unnecessary size and features.

4.9 Externalities

Externalities refer to costs or benefits associated with a particular economic activity or transaction that do not accrue to the participants in the activity. For example, carbon emissions associated with fossil fuel combustion are a negative externality because they cause climate change, adversely affecting human and ecosystem health well beyond that of energy suppliers and consumers. There are also positive externalities, and here, the issue is the difference between private and social gains. For example, research and development (R&D) activities are widely considered to have positive effects beyond those who funded the R&D. This is because R&D adds to the general body of knowledge, which contributes to other discoveries and developments. However, the private returns of a firm selling products based on its own R&D typically do not include the returns of others who benefited indirectly. With positive externalities, private returns are smaller than social returns.

To correct such market inefficiencies associated with technical externalities, government interventions are necessary to tax polluters an amount equivalent to the cost of the harm to others. Such a tax would yield the market outcome that would have prevailed with adequate internalization of all costs by polluters. By the same logic, governments should subsidize those who generate positive externalities, in an amount that others benefit.

4.10 Imperfect Information

In a perfect competition, the market information and knowledge are perfect and costless. These knowledge and information include the current and future prices of goods and services, technological options and developments, and all other factors that might influence the economics of a particular investment (Harris and Carmen 1991). In reality, there has never been a perfect competition market, because the listed conditions can never be met. A number of market failures due to imperfect information, that inhibit investments in energy efficiency, have been identified. These include four aspects: (1) the lack of accurate or perfect information, (2) the cost of information, (3) the accuracy of information, and (4) the capacity to use or act upon information.

First, perfect information requires accurate future energy demand and prices, but the future is unknown and not predicable. Uncertainty and risk are imposed on almost all projects and cause many unknown transaction costs. These unresolvable uncertainties significantly affect the value of energy efficiency investment.

Second, even when information is potentially available, it costs time and money to acquire. Since information is not free, market players often act without full information of the market, which leads to the market failure. Consequently, the shortage of full information resulting from the acquisition or search costs is a prominent failure in the energy services market.

Third, accurate information is difficult to obtain, since information stakeholders usually have strategic reasons to manipulate it in order to inflate its value. Self-interest and self-promotion may motivate sellers to provide misinformation to clients. The costs of acquiring additional information may be high enough to inhibit acquisition of sufficient unbiased information to overcome well-distributed misinformation.

Finally, firms and individuals are limited in their ability to store, retrieve, and use energy efficiency information. Due to the quantity and complexity of information pertinent to decisions on energy efficiency investment, energy efficiency investors, financiers, and decision makers do not have professional capacities or staff to convert data into useful information in a timely manner.

A number of approaches can be used to help combat informational asymmetries. These included the following:

1. Government regulation to force producers to provide accurate information about products through accurate labelling;
2. Public broadcasts to improve knowledge;
3. Government laws to force public limited companies to be more transparent and to have them audited to ensure accuracy;
4. Government regulation on advertising standards to make advertising more informative and less persuasive;
5. Establishment of government regulators and watchdogs to ensure that firms compete fairly and investigate abuse of market dominance by firms with monopoly power.

4.11 Customer Inertia

In physics, inertia is the resistance of any physical object to any change in its state of motion, including a change in direction. In energy efficiency, customer inertia refers to the tendency of customers, including individual energy end users and energy managers, and decision makers in industrial and commercial firms and businesses, to keep using the exiting inefficient energy technologies, equipment, and appliances even if they know it is cost-effective to phase them out and use efficient technologies, equipment, and appliances. The customer inertia is one of the fundamental barriers to energy efficiency market and can happen to every industrial facility and every commercial and residential building. A couple of factors cause the customer inertia. First, physiologically, customers prefer to use their old technologies and equipment. For example, many households do not like the appearance of compact florescent lamps (CFL). They prefer to use incandescent lamps, although they are not efficient. Second, financially, many entrepreneurs prefer to pay higher annual operation costs which contain the running costs of the inefficient equipment, rather than to pay a one-time capital investment for efficient technologies (Yang 2006, 2009). Government regulation to mandatorily phase out inefficient equipment and appliances will help overcome this barrier.

4.12 Lack of Capacity in Developing Countries

Lack of capacity in energy efficiency project development is a major barrier in developing countries. Building capacities in energy efficiency policies, finance, and technologies for developing countries will help remove this barrier. Many events such as the World Summit on Sustainable Development reaffirmed the priority of building the capacity of developing countries in clean energy and climate change (UNEP 2002). The European Commission has funded the European Union (EU)—United Nations Development Programme (UNDP) Climate Change Capacity Building Programme to strengthen the capacity of developing countries in areas such as energy efficiency monitoring, reporting, and verifying as well as designing low emission development strategies. The global environment facility (GEF) listed 11 dimensions in capacity building for energy efficiency project development and implementation (Yang 2013). They were as follows: (1) awareness and knowledge; (2) national policy, legal, and regulatory frameworks; (3) institutional mandates, coordination, and processes for interaction and cooperation among all stakeholders; (4) information management, monitoring, and observation; (5) mobilization of science in support of decision making; (6) financial resources and technology transfer; (7) incentive systems and market instruments; (8) negotiation skills; (9) cooperation and networking within regions; (10) institutional management and performance; and (11) individual skills and motivation in key institutions.

4.13 Summary

Energy efficiency barriers cause market failures and enlarge energy efficiency gaps. This chapter reviews these barriers and lists 11 major ones that lock energy efficiency investments in developing countries. Although these barriers come from many disciplines including economics, finance, market, technology, engineering, anthropology, psychology, and sociology, they can be overcome by government policy and regulations, and capacity building. Various energy efficiency professionals and agencies have undertaken many analyses on the barriers, and many government policy interventions have been suggested to overcome these market barriers. These interventions include, but not limited to, the following:

1. Energy sector and energy pricing reforms to use marginal cost of production for energy pricing;
2. Government laws and regulation to help combat information asymmetries;
3. Public campaigns to increase awareness of energy efficiency;
4. Mandatory energy efficiency standards and labels for buildings, appliances, and other equipments to inform consumers of the features of the energy-efficient technologies;
5. Transparent and extensive communications in the market to avoid incorrect market information on energy efficiency;
6. Multiple projects in program development to cut down transaction costs for each project;
7. Government supported de-risk funds to lower interest rates of bank loans for small business entities;
8. Government laws and disincentive taxes on inefficient equipment, and laws and incentive subsidies on efficient equipment to phase out inefficient appliances; and
9. Capacity building for developing countries.

References

Blumstein C, Kreig B, Schipper L, York C (1980) Overcoming social and institutional barriers to energy efficiency. Energy 5(4):355–372

DeCanio SJ (1993) Barriers within firms to energy efficient investments. Energy Policy 21(9):906–914

Foxon T (2003) Inducing innovation for a low-carbon future: drivers, barriers and policies. Carbon Trust, London

Golove W, Eto J (1996) Market barriers to energy efficiency: a critical reappraisal of the rationale for public policies to promote energy efficiency, LBL-38059, UC-1322, University of California, Berkeley, California 94720

Harris R, Carmen J (1991) The political economy of regulation: an analysis of market failures. In: Sethi SP, Steidlmeier P, Falbe CM (eds) Scaling the corporate wall. Prentice Hall, Englewood Cliffs

IEA—International Energy Agency (2007) Lights labour's lost. OECD, Paris. https://www.iea.org/publications/freepublications/publication/name,3644,en.html

IMF—International Monitory Fund (2013) Reforming energy subsidies IMF policy advice. http://www.imf.org/external/np/fad/subsidies/index.htm. March 27. Cited 26 July 2014

Montalvo C (2008) General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007. J Cleaner Prod 16(1):S7–S13

Palmer J (2009) Placing barriers to industrial energy efficiency in a social context: a discussion of lifestyle categorization. Energ Effi 2:263–270

Ruderman H, Levine M, McMahon J (1987) The behavior of the market for energy efficiency in residential appliances including heating and cooling equipment. Energ J 8(1):101–124

Sorrell S, Schleich J, Scott S, O'Malley E, Trace F, Boede U, Ostertag K, Radgen P (2000) Barriers to energy efficiency in public and private organisations. SPRU (Science and Technology Policy Research), University of Sussex, Brighton

Sorrell S, Schleich J, O'Malley E, Scott S (2004) The economics of energy efficiency: barriers to cost-effective investment. Edward Elgar, Cheltenham

UNEP (2002) Capacity building for sustainable development: an overview of UNEP environmental capacity development initiatives. ISBN: 92-807-2266-2. Printed by UNEP

Yang M (2006) Energy efficiency policy impact in India: case study of investment in industrial energy efficiency. Energy Policy 34(17):3104–3114. doi:10.1016/j.enpol.2005.05.014

Yang M (2009) Energy efficiency improving opportunities in a large Chinese shoe-making enterprise. Energy Policy 38(1):452–462. doi:10.1016/j.enpol.2009.09.036

Yang M (2013) Closing the gap: GEF experiences in global energy efficiency. Springer, New York. ISBN 978-1-4471-4516-5. http://www.springer.com/engineering/energy+technology/book/978-1-4471-4515-8

Chapter 5
Overall Methodology in This Study

Abstract The previous chapters reviewed the important position of energy efficiency as the first fuel in national energy development strategy and 11 market barriers that prevent energy-efficient technologies from being fully invested and deployed. This chapter presents a methodological framework for the book. The framework expanded to five areas: government policies and regulations; theory and example of economic and financial analyses for projects; project financing; energy service companies (ESCOs) and private investments; and energy-efficient technologies and green transport. Two case studies are presented as a foundation to support the methodology framework. Presented at the end of the methodology are conclusions from the analysis. Finally, data collection to support this study is briefly introduced in this chapter.

5.1 Methodological Framework

The methodology used in this study consists of ten steps that lead to fulfill the objective of the study. Recall that the objective of this book is to enhance knowledge of energy efficiency for students and young professionals from perspectives of national energy security, government laws and policies, technologies, engineering, finance, and on-ground equipment operations. The methodology that supports the study to achieve the objective has the following ten steps (see Fig. 5.1).

The first step with two tasks is to review the changing role of energy efficiency as a contributor to national energy security from a hidden fuel to the first fuel and as the first tool to mitigate climate change. The first task of this step is to present a picture of global energy savings achievements and potential of further investments in energy efficiency and climate change. The second task in the first step is to identify energy efficiency investment gap worldwide. Although the review focuses on OECD countries, energy efficiency has indeed contributed national energy security in all countries worldwide, given that energy intensity in all energy-importing countries has decreased over the past four decades (EIA 2014). The review also reviles the US \$1.9 trillion international energy efficiency investment gap, namely the difference

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_5

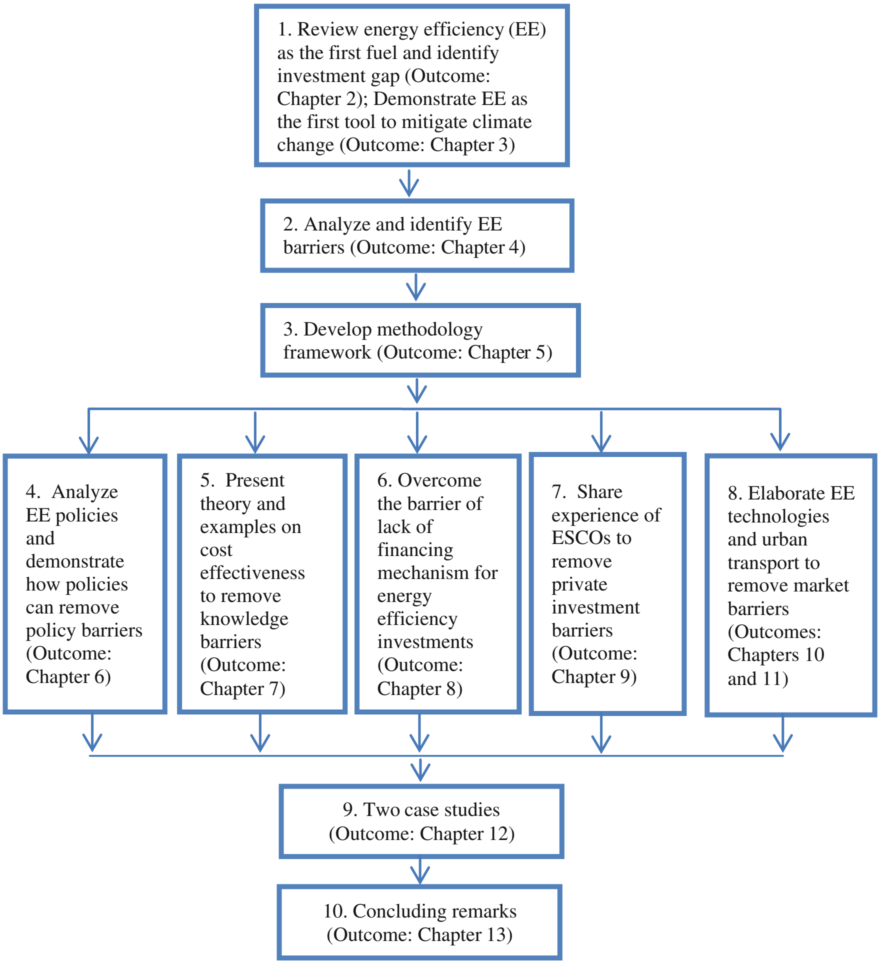


Fig. 5.1 Methodology framework for this study. *Source* Authors' design

between levels of investment in energy efficiency that appears to be cost-effective based on engineering economic analysis and the lower levels of investments actually occurring. Chapter 2 presents the review results, and Chap. 3 shows how the USA and China use energy efficiency as the first tool to mitigate climate change over the next two or three decades.

The second step of the methodology is to analyze and identify energy efficiency barriers. It traces why there is such a huge energy efficiency investment gap and why the low-hanging fruits of energy efficiency have not been fully picked up. This step discovered that there exist a large number of financial, social, psychological, technical, and commercial barriers preventing energy efficiency technologies from being fully invested and deployed. These include (1) subsidies to fossil energy,

(2) high transaction costs, (3) invisibility of energy efficiency projects, (4) misplaced incentives, (5) lack of access to financing, (6) misplaced pricing imposed by regulation, (7) gold plating and inseparability of features, (8) externalities, (9) imperfect information, (10) customer inertia, and (11) lack of capacity. More detailed information is presented in Chap. 4. Removing these barriers in the energy efficiency market and therefore facilitating capital investments to close the energy efficiency gap become focal points in the following chapters of the book.

With a clear objective and intensive literature review, a methodological framework is designed for the study in the third step. The methodology comprises the theoretical analysis of energy economics; energy efficiency project financing; and principles associated with energy efficiency policy, regulation, and market development. It encompasses concepts, theoretical model, phases, and quantitative or qualitative techniques. This chapter describes the development of the methodological framework.

The fourth step in the methodology is to analyze at a national level the government policies and the application of the policies in the area to overcome energy efficiency barriers and close investment gaps. The uses of these policies are applicable from national government level to provincial/state level, city level, enterprises level, and at individual home owner level. The outcome of the analysis is presented in Chap. 6.

Step five is to provide economic analysis tools for project developers to find most cost-effective energy efficiency projects for investments. This step aims at overcoming the barriers of energy end users' lacking of knowledge and short of capacity in identifying and examining energy efficiency projects. It presents basic theory on cash flow analysis for projects and demonstrates a standard cost-effectiveness analysis approach from the perspective of energy end users, which is the most commonly used approach to assessing the cost-effectiveness of energy efficiency projects and programs. This step also discusses details on the input data of the formula and ways to make the formula of the standard approach capable of performing the cost-effectiveness analysis. The approach described in this step is to (1) present the mathematical formulas for the approach; (2) specify the components of benefits and costs for the approach; (3) illustrate the data required to calculate the benefits and costs in the approach; and (4) show applications on using the analysis results in energy efficiency policy development. With the cost-effectiveness analysis approach, an energy end user can test whether his/her capital investments in energy-efficient technologies are profitable. The outcome of this step is shown in Chap. 7.

Step six shows how to overcome the barrier of lack of financing mechanism in the market for energy efficiency investments in most developing countries with government policies. An effective financial mechanism can be in the form of rebates, grants, or loans for energy efficiency improvements, direct income tax deductions for individuals and businesses, and exemptions or reduced sales tax on eligible products. Incentives offered by national governments are generally in the form of tax incentives. Utilities can rebate energy-efficient appliances and equipment for any energy end users in the system, which facilitates energy efficiency investments. Private-sector-based ESCOs and individual energy end users or customers are beneficiaries of the governments' and utilities' financial mechanisms. The success of a financial mechanism is to attract the private ESCOs and energy end users to apply for loans in the local banks or to use their equity and funds in financing energy efficiency projects. In the real energy efficiency financing market, there are two types of energy efficiency financing: (1) loans, debt, and equity financing; and (2) off balance sheet financing. In the first type, capital investments in projects appear on the balance sheet of companies, which likely increases the debt/equity ratio of the company. In the second type, all equity will not appear in the company's balance sheet and no new capital equipment purchased. In step six, an overview of four major energy efficiency finance models prevalent today in the world is also presented. These are dedicated credit lines, risk-sharing facilities, energy saving performance contracts, and leasing for energy efficiency financing. While many other energy efficiency finance options also exist, these four models are among those attracting significant interest from both the private sector and the public sector worldwide, particularly in developing countries. This step also provides an analysis of the main challenges, legal considerations, and opportunities associated with scaling and deploying these models. The outcome of this step is presented in Chap. 8.

In the seventh step, the focus of the study is to remove barriers of lack of local financial mechanisms and local capacities and the strategy is to foster ESCOs in the energy market. Different models of ESCOs in different financial markets in various countries are analyzed, and case studies are undertaken for China, India, Ukraine, and Brazil. The analysis of this sept covers national government subsidies for energy consumption, market-based financial mechanism for ESCOs, the impact of the private sector in project co-financing, and successful incentives to ESCO development in the market. Analyses in ESCO development are based on data from 25 projects in 39 countries that were financed by the GEF. Four comparison studies were undertaken in ESCO policy, capital investments, and ESCO operations for the four aforementioned countries: China, India, Ukraine, and Brazil. It highlights experiences and lessons in financial mechanism development and ESCO business development. The outcome of this step is indicated in Chap. 9.

Step eight is to demonstrate energy-efficient technologies that have been widely used in the energy market. Government policies, market financing mechanisms, and ESCOs' services described in the previous steps should be applied in projects that involve in installations of energy-efficient technologies on specific engineering sites, buildings, and homes. Energy-efficient technologies in the market include lighting, household appliances, building envelope, window, doors, heating, ventilation, air-conditioning, heat exchangers, working fluids, geothermal heat pumps, water heating, sensors and controls designed to measure building performance, smart grids, industrial process, electrical motors, and green transport. In step eight, only several most commonly used energy-efficient technologies are studied. These include lighting, home appliances, industrial motors, and green urban transport. The descriptions of these technologies are further supported by two case studies in the next chapter. The purpose of this step is to guide readers to gain more knowledge from policy and finance level to energy engineering and technology level. The outcome of step eight is displayed in Chaps. 10 and 11.

Then, step nine is to show case studies and Chap. 12 presents two case studies. Covering policy and financial market development to raise energy efficiency of china's electric motors, and investment practice in global industrial energy-efficient boiler steam systems, these case studies demonstrate, with real energy efficiency and transportation projects, the application and use of national government policies and regulations, economic and financial analysis tools, project financing principles, ESCOs, technology selections, and equipment operations.

The final step in the methodology is to summarize the analysis and present the conclusion. All chapters are summarized and consolidated, and key results that crosscut the various chapters are presented in Chap. 13.

5.2 Data Used in This Study

Data for this study were collected from several sources. The primary data source is from the authors' database that has been accumulated from teaching and working on-ground over the past 20 years. The data are supplemented with other data sources from literature reviews, including publications on energy and GHG emissions of the IEA, the database of the World Bank Development Indicators, evaluation documents of the World Bank Independent Evaluation Group, and statistical year books of some developing countries.

The largest data source for this study is from the authors' database. This includes (1) policy negotiation with government stakeholders; (2) the theory of economic and financial analyses for projects; (3) engineering and technology data for equipment and machinery in a factory; and (4) post-evaluation data and documentation.

The publications of the IEA are second largest sources of energy and environmental data for this study. These included publications on energy efficiency policy recommendations and carbon emissions, energy efficiency economics, and efficient technologies. World Bank Development Indicators are used to support this analysis. These indicators are developed and compiled from officially recognized international sources. They represent the most current and accurate global development data available and include national, regional, and global estimates. For example, in this study, energy intensities for some developing countries are calculated from countries' final energy consumption and GDP as reported in the indicators.

Several project evaluation reports of the World Bank Independent Evaluation Group (IEG) are also used in this analysis. The IEG is an independent unit within the World Bank that reports directly to the World Bank Board of Executive Directors. The IEG's Web site provides access to over 1,000 evaluation documents and is available to the public. This analysis includes data on projects from IEG documents.

Additional data used in this analysis were obtained from some developing countries. For example, the People's Republic of China (PRC) Ministry of Finance and the Ministry of Environmental Protection is a source of information on GEF China boiler project covered in the case study.

In summary, the primary sources for data used for the analysis are from the authors' personal library. These sources are augmented with information from the IEA, the World Bank, the International Finance Corporation (IFC), and the developing countries to verify and cross-check the data.

Reference

EIA—Energy Information Administration (2014) Energy intensity—total primary energy consumption per dollar of GDP, US Department of Energy. http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=92&pid=46&aid=2. Cited 28 July 2014

Chapter 6
Energy Efficiency Policies

Abstract This chapter presents energy efficiency policies at the national government level and identifies some prominent policy trends. Four key findings emerged from this chapter: (1) It is necessary for the government to constantly revise or strengthen national energy efficiency policies to make these policies suitable for the changing of national realities; (2) an effective government policy in one country may not be applicable to another country, although many national government policies can be shared among different countries; (3) there is no widely accepted methodology for evaluating effectiveness of energy efficiency policies; (4) coordination among the national government policy makers and policy implementers is increasingly important; and (5) there are opportunities to significantly improve policy performance through a unified strategy.

6.1 Introduction

Implementing energy efficiency policies is one of the most cost-effective instruments for overcoming barriers to energy efficiency. For this reason, energy efficiency polices have been essential elements of energy sector reform for many countries since the late 1970s. The Energy Policy Act of 2005 (EPAct05) and the Energy Independence and Security Act of 2007 (or in short: EISA 2007), for example, were most effective federal legislations to expand and strengthen the US energy efficiency policies. Similarly, China developed its Energy Savings Law in a period of over 15 years. The Law became a foundation of the Chinese energy efficiency policy that guides the provincial governments, firms, and households in energy efficiency investment and management. Many other countries, including Australia, Japan, India, Brazil, have also developed their national energy efficiency policies since the 1970s. Provisions in these energy efficiency policies include efficiency of appliances and lighting; energy savings in residential, commercial, and government buildings; the efficiency of industrial manufacturing plants; and the

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_6

efficiency of electric power generation, transmission, and end-use. These actions began to contribute to new federal, state, and local policies, programs, and practices across the world.

The purpose of this chapter is to demonstrate the design of effective and least cost energy efficiency policies in context of energy security and economic development for a country. It is important for policy makers to examine whether or which energy efficiency policies are needed in the presence of economy-wide energy pricing and pollution mitigation. It is worthwhile checking the complementarity of energy efficiency policies to reduce transaction cost burdens imposed on individuals, firms, and the country. This chapter aims to address the following questions:

1. How are the national government energy efficiency policies initiated (with two examples)?
2. Which policy interventions are required to overcome energy efficiency barriers?
3. What is the impact of those policy measures on removing the energy efficiency barriers?

6.2 Necessities for Public Policies Promoting Energy Efficiency

There are two key reasons for governments to use policies to intervene distorted energy service markets. First, due to energy efficiency barriers, the market fails to achieve the socially optimal distribution and use of energy resources. Individuals and firms are seeking to maximize their personal and economic welfare in the short run, but not necessarily social and environment benefits in the long run. For example, CFLs and LED are economically and technically proven energy-efficient lighting technologies. In the long run, using these technologies can benefit individuals in cutting home energy bills and enhance national economy by reducing energy consumption and mitigating carbon emissions. Due to energy efficiency barriers and market failures, these energy-efficient technologies have not been used as widely as they should be. Governments could use policies to guide firms and individuals on investment in energy-efficient equipment and appliances. In many countries, such as EU countries, Australia, China, and many states in the US, by law, governments have recently banned production and sale of incandescent lamps in the market. As a result, individuals and firms have to switch to energy efficient-lighting technologies.

Second, it is necessary for the government to invest in some areas of energy efficiency where individuals and firms are reluctant to do. These include (1) energy efficiency research and development (R&D), (2) development and acquisition of information in energy efficiency for the public, and (3) de-risk measures associated with investments in new energy-efficient technologies. Investment in these areas for each of the individual households and firms is high. The government should invest in these areas and share the results and outcomes with the public, which can greatly reduce costs for firms and individuals, and facilitate the development of energy efficiency markets.

6.3 Sufficient Conditions for the Use of Policies for Energy Efficiency

The sufficient condition for the government to use policies is the effectiveness of the policies in the market to improve energy efficiency. Assessing the magnitude of market failure and the tolerance of the market to the new government policy can help the government to determine whether the policy is effective. For example, when considering imposing tax on diesel as car fuel, the government has to understand the following: (1) what are the benefits of the tax policy in terms of energy efficiency improvement nationwide; (2) what are the economic and social losses of the tax policy; (3) who are the major taxpayers; and (4) what is the maximum tolerance of taxpayers on the increase of fuel prices.

Sometimes, it takes long time for energy efficiency policies to be effective in the market because the society, firms, and individuals need time to understand the policies and build their capacities for implementation. As such, evaluation of government policy effectiveness should be conducted at least five years after the policy inception. For example, an analysis on 47 energy efficiency investment projects was undertaken in 2012 (Yang 2013). These 47 projects involved government policy implementations in the 1990s and the early 2000s. The time period between policy implementation and policy evaluation in the analysis was approximately 10 years.

6.4 Documentation of Global Energy Efficiency Policies

Many attempts to develop energy efficiency policies and measures have been made and documented. Examples include as follows: (1) The work by a group of international experts on energy efficiency convened by the United Nations Foundation (UNF 2007); (2) a study commissioned by the World Wildlife Fund (WWF) International (Klessmann et al. 2007); (3) an analysis conducted by the IEA (Jollands et al. 2010); (4) an energy savings policy report commissioned by the European Climate Foundation (ECF); and (5) energy efficiency investment policies of the GEF documented by Yang (2013).

The UNF report is based on a detailed study of the potential of energy efficiency and the importance of spurring decisive action on climate change during 2010–2020 (UNF 2007). The report presents 22 recommendations on energy policies and measures that are related to national strategies, international cooperation, and data collection. These 22 recommendations cover key economy-wide areas including buildings, industry, transport, energy supply, and energy efficiency for developing countries and countries with economy in transition. The objective of these recommended actions is to assist the Group of Eight (G8) countries in meeting the goal of a 2.5 % annual rate of energy efficiency improvement from 2012 to 2030.

The WWF International-commissioned report presents a portfolio of energy efficiency policies and measures. The recommendations are categorized into eight areas for action by all countries in the world.

The IEA also proposed 25 recommendations on energy policies and measures that were prepared under the mandate of the G8 Gleneagles Plan of Action (Jollands et al. 2010). In fact, energy efficiency has become an important item on the G8 agenda. At the Gleneagles Summit in July 2005, G8 leaders addressed the challenges of climate change, securing clean energy and sustainable development, and adopted a Plan of Action. A dialog was also launched between G8 and other significant energy-consuming countries. Brazil, China, India, Mexico, and South Africa were also represented at the Summit. The IEA 25 recommendations are applicable not only to OECD countries, but also to developing countries. The IEA published nine policies and measures in energy efficiency covering: (1) education and outreach, (2) financial, (3) incentives/subsidies, (4) policy processes, (5) public investment, (6) research and development, (7) regulatory instruments, (8) tradable permits, and (9) voluntary agreement (IEA 2012).

The Energy Savings 2020 report, commissioned by the ECF, assesses the impact of current EU energy and climate policies. It makes recommendations on the design of an overarching and binding energy savings policy framework to achieve the EU's 20 % energy savings target by 2020. The report analyzes the opportunities and challenges of four policy options: (1) an economy-wide energy savings target at the EU level, (2) end user targets set at the EU level for sections of the economy, (3) an economy-wide energy savings target for each member state, and (4) end user targets for member states for sections of national economies.

GEF policy recommendations for GEF's participating countries have been made and executed during GEF project implementation. As of June 2012, the GEF had invested in over 270 energy efficiency projects worldwide. All projects have policy initiative and development components. For example, in a GEF project aimed at encouraging the adoption of more efficient boilers in China, the GEF recommended new national standards for thermal efficiency, a new environmental emissions policy, and a new coal quality policy to the Chinese government. Furthermore, some energy efficiency policies and measures recommended by the IEA have also been applied in GEF energy efficiency projects (Yang 2013).

6.5 Energy Efficiency Policies to Benefit the Society

An energy efficiency policy should create a win situation and minimize a loss situation to any individual party in the society. Measuring direct costs and benefits alone may not capture all impacts of energy efficiency policy on social welfare.

If only based on a direct accounting of dollars spent and energy saved in the whole society, an energy efficiency policy that appears cost-effective to the government may not be cost-effective to firms or to individuals. For example, in an electricity savings project where the time-of-use scheme is implemented, non-participants may inappropriately subsidize participants in the scheme. For another example, while calculating the net present value of an investment in an energy efficiency project, the government may use 8 % as discount rate, while a firm may use 10 % since the weighted capital cost of the firm is 10 %. To make sure energy efficiency investment is in a win situation to the society, a cost-effectiveness analysis should be undertaken for each of the project stakeholders including non-participants.

6.6 Government Policy and Regulation for Utilities

Private-owned and public-owned utilities are the two types of energy utilities providing services to customers. Government policies and regulation models are also developed for the two different types of utilities accordingly. The private-owned utilities are private companies with ownership shares held by stockholders. These private utilities play major roles to provide energy services to customers in almost all OECD countries. These utilities are primarily regulated at the national or state level, where public service commissions (PSCs) are responsible for overseeing and authorizing investment decisions, operations, and customer rates. Publicly owned utilities are owned by government ministries and are not generally regulated by state public service commissions. They are overseen by a variety of somewhat comparable organizations such as national government ministries, or federal regulators. These public utilities play major roles in providing energy services in many non-OECD countries.

For both private-owned and public-owned utilities, certain aspects of utility regulation and policy are especially critical for enabling and supporting utility energy efficiency programs. Experience has shown that without very direct and supportive regulations and policies, utilities will not develop and offer significant customer energy efficiency programs. For any utilities to do so, they need confidence in recovering their program costs. Beyond program cost recovery, utilities also face financial disincentives and barriers to investments in energy efficiency. Consequently, many countries have enacted regulations and policies to create new business models to provide incentives for developing successful and effective energy efficiency programs.

State policy makers and regulators also can provide clear direction and incentives to utilities about the importance of energy efficiency. As the first step, legislators and regulators often require utilities to offer energy efficiency programs; they also set up mechanisms for utilities to recover their costs through rate case proceedings. For example, in the state of Maryland of the USA, in 2014, a customer can get a \$100 cash rebate when purchasing a super-efficient ENERGY STAR® certified washer with a modified energy factor (MEF) of 2.4 or above and water factor (WF) less than or equal to 4.0 (Pepco 2014).

6.7 Examples of Energy Efficiency Policies

Since the late 1970s, various government energy efficiency polices have been developed to facilitate energy efficiency investments and improvements worldwide. This section only selects several energy polices developed by the US and Chinese governments as examples.

6.7.1 The USA

The US federal government has a long history to establish policy incentives to address energy efficiency in buildings. In 1975, with the US Energy Policy and Conservation Act (or in short: EPCA 1975), (Legislative Reference No. PL 94-163), the US Congress called for the establishment of minimum standards of energy efficiency for many major appliances (DSIRE 2013). The EPCA 1975 has been subsequently amended by succeeding energy legislation. In 1978, the US National Energy Conservation and Policy Act (NEPCA), with Legislative Reference No. PL 100-12, authorized the US Department of Energy (DOE) to set mandatory standards for thirteen household products. In 1988, the US National Appliance Energy Conservation Act (NAECA), with Legislative Reference No. PL 100-35, established national standards for home appliances and schedules regular updates through 2012. In 1992, the US Energy Policy Act (I) (EPAct92), with Legislative Reference No. PL 102-486, expanded standards to include additional commercial and residential appliances. In 2005, the US Energy Policy Act (II) (EPAct05), with Legislative Reference No. PL 109-58, updated testing procedures for appliances. In 2007, the US Energy Independence and Security Act (EISA 2007), with Legislative Reference No. PL 110-140, established new standards for a few equipment types not already subjected to a standard and updated some existing standards. For example, EISA 2007 requires energy-efficient lighting to be deployed in two phases. First, by 2012–2014, common light bulbs are required to use about 20–30 % less energy than lamps in 2007. Second, by 2020, light bulbs must consume 60 % less energy than in 2007. This requirement has been effectively phasing out incandescent bulbs. ESCA 2007 also requires that all existing and new federal buildings lead by example. Existing buildings must reduce energy consumption 30 % by 2015, compared with the 2003 level, through building upgrades and efficient appliances. New buildings must achieve efficiencies of 30 % better than the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) code, and the International Energy Conservation Code (IECC) (Doris et al. 2009).

6.7.2 China

The Chinese government commenced its energy efficiency policy in the early 1980s with the establishment of energy savings agencies at various governmental levels. Over 200 Energy Savings Centers were set up by local governments and sectoral agencies (Crossley 2013). Their mission was to assist enterprises in designing energy efficiency projects, using energy equipment appropriately, and providing training and information. These Centers were originally supported by the government and later became dependent on revenues from sales of their services. Today, many of these Centers become ESCOs.

In 1982, while establishing energy savings agencies, the Chinese government began drafting the Energy Savings Law, which was continually revised over a period of 15 years. In 1997, the Law was finally passed by the National People's Congress. Comprising policy principles rather than specific provisions, the Law provided a policy framework that enabled China's 33 provincial-level governments to promulgate detailed local bylaws and regulations on energy efficiency. The Law required all levels of government to arrange funds to implement energy efficiency measures.

The Law also required local governments to establish a system for discontinuing backward, over energy-intensive, energy-consuming products and equipment. This led to major programs to close down old, small-scale, and inefficient energy-intensive industrial capacity, including the progressive closure of emissions-intensive power plants.

The 1997 Energy Savings Law identified key energy-intensive entities as those with an annual energy consumption equivalent to more than 10,000 tonnes of standard coal equivalent (tce). These entities were required to appoint an energy manager and to submit periodic reports to the government on energy consumption, energy efficiency, and the energy efficiency measures they implemented. The Law also authorized various levels of government to "supervise and manage" energy efficiency work in their jurisdictions. This led to the establishment of Energy Savings Supervision Centers by many provincial-level governments, with duties to inspect facilities, levy fines on offenders, and even shut down the facilities of the offenders.

In 2004, in response to the increasing in energy intensity commencing in 2002, the national planning body in China issued the Medium and Long-Term Energy Conservation Plan. The overriding goal of the Plan was to reduce national energy intensity by 20 % between 2005 and 2010. The Plan specifically defined "Ten Key Energy-Saving Projects," including: coal-fired industrial boiler retrofits, residual heat and pressure utilization, petroleum saving and substitution, motor system energy saving, and energy system optimization.

The Plan set energy intensity targets between 2010 and 2020 for individual energy-intensive industries, including cement, steel, petrochemicals, oil refining, and electricity generation. The Plan also specified raising energy efficiency standards for major energy-using appliances to international levels by 2010.

In 2007, the National People's Congress passed an amended Energy Savings Law to strengthen the provisions of the 1997 Law. The 2007 Law significantly increases the importance of energy efficiency by specifying: "The Country implements an energy strategy of promoting energy savings and development concurrently while giving priority to energy savings." The 2007 Law also includes a provision that the Country "will implement a system of accountability for energy efficiency targets and a system for energy evaluation whereby the fulfilment of energy savings targets is taken as one part of the performance evaluation of local people's governments and their responsible persons." The Law therefore makes achievement of energy efficiency targets a component of the performance evaluation of local governments and their officials. Individual government officials may be subject to sanctions if energy savings targets in their areas of responsibility are not achieved.

The 2007 Law requires key energy-using entities to report to government annually on their performance of achieving energy conservation targets. The Law authorized the imposition of penalties on entities that fail to achieve targets or implement energy conservation measures.

The 2007 Law also authorizes the implementation of a system of differential electricity pricing whereby enterprises in some energy-intensive industries can be charged higher prices if their operations fail to meet energy intensity targets. Differential electricity pricing is applied to energy-intensive enterprises in eight industries. Enterprises are divided into three categories according to resource consumption and technology level. Inefficient enterprises pay surcharges on the standard electricity price.

In 2011, complying with the 2007 Law, China, introduced an extensive set of efficiency target and measures at the start of its 12th Five-year Plan (2011–2015), with the objective of reducing energy intensity 16 % by 2015 compared with the 2010 level. At least, two concrete policy actions have been taken to realize the target. The first is the allocation of energy efficiency target to provinces, cities, and sectors. In the past 11th Five-year Plan, provincial targets were set based on rapid assessment and negotiation, and most were set close to the national target of 20 % reduction in intensity over the five-year period. By 2011, some provinces exceeded their targets and developed robust management systems for ongoing improvement. Other provinces struggled and took extreme short-term measures to reach their targets. For the 12th Five-year Plan, while allocating the target, the Chinese government used a more scientific methodology to better estimate the varying potential for energy saving across the provinces and cities and sectors.

The second is called energy benchmarking for industry. Energy benchmarking is defined as the process of measuring energy performance of an individual plant or industrial sector against a common metric that represents "standard" or "optimal" performance of a reference plant or an industrial sector (Phylipsen et al. 1996). It can also be designed to compare the energy performance of a number of plants against one another or to compare the plant against itself in different time periods or under different operating conditions. Comparing an individual plant or industrial sector against itself in different periods or operational conditions is sometimes necessary, especially in the following two situations: (1) The relevant information of other plants or industrial sectors is not available or insufficient due to intense competition or proprietary information, but the plant or industrial sector knows itself well and wants to evaluate its own performance in different operational conditions; (2) to evaluate the energy efficiency improvement of a plant or industrial sector. However, if more information is available, it is better to benchmark to the industry leaders to better understand how large the difference in performance is as well as what causes the difference. Benchmarking is often regarded as the search for industry best practices that will lead to the superior performance. Energy benchmarking can also be viewed as the search for industry best practices in energy use that will lead to superior energy performance (Camp 1989). Only the comparison to and understanding of the best practices of industry or functional leaders will ensure superiority. Therefore, establishing targets and improving energy efficiency based on best practices is preferred and critical for improving the energy economy worldwide in terms of energy conservation and reducing emissions. The energy efficiency action of the Chinese benchmarking is very similar to the Japanese Top Runner Program.

6.8 Monitoring and Evaluation of Government Policy Effectiveness

Monitoring, reporting, and evaluation of the effectiveness of energy efficiency policies may take a long time, but it is necessary to do so in order for the government to make better energy efficiency policies. For example, with its energy efficiency policy, in 2005, China targeted to reduce its energy intensity by 20 % at the 2005 level during 2006–2010. Statistic data in 2006, 2007, and 2008 showed that energy intensity was not decreasing as the government expected. By reinforcing the energy policy and provisions, the government forced closing many inefficient power plants and industrial facilities during 2009 and 2010. As a result, China achieved reducing its energy intensity by 19.6 % in 2010 at its 2005 level, almost meeting its panned target. Without continued monitoring, reporting, and evaluation of the energy efficiency policy, China would not have achieved its 19.6 % of energy intensity reduction during 2006–2010.

6.9 More Examples of Energy Policies by Countries

Energy efficiency policies and programs were constantly strengthened and renewed in many countries. The following presents several examples of governments' efforts in enhancing their countries' energy efficiency policies and programs in 2012–2013.

6.9.1 Energy Efficiency Policies

1. African countries are making progress in energy efficiency policy development and implementation. Economic Community of West African States (ECOWAS) started a program in buildings to adopt appliance standards and labels by 2014, develop a region-wide standard for buildings, and phase-out incandescent lamps by 2020. In South Africa, the government initiated the Manufacturing Competitiveness Program with US$0.6 billion to upgrade current industrial production facilities.
2. The Australian government has taken further steps as part of the Clean Energy Future package to exploit the remaining energy efficiency potential. The government invested US$1.2 billion in the Clean Technology Program to improve energy efficiency in industry and support research and extension of the Energy Efficiency Opportunities Program, which has been opened up to medium-size energy consumers. The establishment of the Clean Energy Finance Corporation was endowed with a US$10 billion fund that would be invested in clean energy including energy efficiency. Discussion has also begun on setting efficiency standards for light-duty vehicles.
3. Brazil has joined other countries in adopting incentives to increase energy efficiency in the transport sector. The Inovar-Auto program encourages technology innovation by requiring automobile manufacturers to increase the efficiency of cars up to 2017 in order to qualify for tax breaks. Its effective implementation is expected to increase the efficiency of light-duty vehicles by 12 % as a minimum target by 2017. The Inovar-Auto program is seen as a first step toward the establishment of mandatory energy efficiency targets.
4. Canada extended fuel-economy standards for cars to 2025, introduced stringent performance standards on new power plants, banning the construction of coal-fired power stations without being equipped with carbon capture and storage technologies. The Canadian government introduced Minimum Energy Performance Standards for several products, including lighting, water heating, and air conditioning. In the power sector, the government introduced minimum performance standards requiring new power stations not to exceed 420 tonnes of CO_2 per gigawatt-hour.
5. The Chinese government continued its energy price reforms by more frequent adjustments in oil product prices and an increase in natural gas price by 15 % for non-residential users. China also introduced energy efficiency standards for new buildings and the refurbishment of existing dwellings.
6. In the EU, within the framework of the Eco-design Directive, regulations for vacuum cleaners and computers are implemented in the buildings sector, and a fuel-economy standard for new cars of 95 grams of CO_2/km by 2020 is agreed in the transport sector.
7. The Indian government made the Energy Conservation in Building Code mandatory for large commercial and residential buildings in eight states, with the objective of reducing energy consumption in buildings with focuses on

lighting and hot water systems. The country's the Minimum Energy Performance Standards for air conditioners have been tightened.

8. Japan added windows and heat-insulating materials to its Top Runner Program in buildings, which was expected to promote technology innovation. In industry, evaluations of industrial consumer efforts will be carried out to reduce electricity use during peak hours.
9. In Malaysia, the government established an overall long-term energy efficiency plan on the basis of a long-term National Energy Efficiency Master Plan. The goal of the energy efficiency plan is to reduce electricity consumption by 10 % in 2020 on the basis of 2012 level (APEC 2013).
10. The Middle East countries took some intensified action on limiting the spiraling electricity consumption from air conditioners, which account for roughly half of electricity demand in that region. Saudi Arabia strengthened its Minimum Energy Performance Standards for air conditioners, and the United Arab Emirates introduced such standards for air conditioners and mandatory energy labeling scheme for all domestic appliances.
11. In Singapore, the Energy Conservation Act has been implemented, requiring a coordinated industrial approach to reporting on energy use, appointing energy managers, and elaborating efficiency improvement plans.
12. The USA announced carbon pollution standards for new and existing power plants. The government also proposed the Energy Savings and Industrial Competitiveness Act of 2013 to strengthen building codes, create financing initiatives for the application of efficient motors, tighten efficiency standards for appliances, and intent to increase fuel-economy standards for heavy-duty vehicles beyond 2018.

6.9.2 Energy Efficiency Labeling Programs

1. National framework replacing seven state and territory legislative frameworks in Australia. Seven appliances covered by the mandatory energy rating labeling scheme. Mandatory disclosure of commercial building energy efficiency in Australia.
2. Mandatory EnerGuide label for eight major household appliances and light bulbs. International ENERGY STAR symbol promoted in Canada.
3. Energy performance certificates mandatory for all new buildings. Labeling in place for household appliances in European member states.
4. Voluntary building labeling program and energy star for office equipment in Japan.
5. Labeling system expanded from 26 products in 2011 to 35 products in South Korea.
6. Mandatory energy guide labeling for most household appliances. Voluntary energy star labeling for over 60 categories of appliances, equipment, and buildings in the USA.

6.9.3 Appliance, Equipment, and Lighting Minimum Energy Performance Standards (MEPS)

By 2013, this policy covered 20 products in Australia, 47 in Canada, 15 in European member countries, 23 in Japan, 26 in New Zealand, and 45 in the USA (IEA 2013).

6.9.4 Transport Fuel Efficiency Standards for Light-Duty Vehicles (LDV) and Heavy-Duty Vehicles (HDV)

1. Australia: for LDV, implemented from 2015; for HDV, included in carbon price mechanism from 2014.
2. Canada: for LDV, published in October 2010 for model years 2011–2016; for HDV, under consideration.
3. EU members: for LDV, require 130/CO_2 per km by 2015; for HDV, under consideration. Switzerland is also implementing these standards.
4. South Korea: for LDV requires 17 km/l by 2015 and 140 g/CO_2 per km by 2015; for HDV, starting in 2015.

6.9.5 Transport Fuel-Economy Labeling for LDV an HDV

1. Australia: for LDV, yes; for HDV, no.
2. Canada: for LDV, EnerGuide label; for HDV, no.
3. EU members: for LDV, yes; for HDV, no.
4. Japan: for LDV, yes; for HDV, yes.
5. South Korea: for LDV, yes; for HDV, no.
6. New Zealand: for LDV, yes; for HDV, no.
7. The U.S.: for LDV, yes; for HDV, no.

6.9.6 Transport Fiscal Incentives for New Efficient Vehicles

1. Canada: Several provinces and territories offer incentives or rebates for the purchase of fuel-efficient vehicles, including electrical vehicles (EVs).
2. European members: Many countries align vehicle taxes with CO_2 emissions.
3. Japan: Registration taxes according to CO_2 emissions and fuel economy.
4. The USA: Tax at federal level; 20 states plus D.C. offer tax incentives, rebates, or voucher programs for advanced vehicles (EVs, plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs), and/or fuel cell vehicles).

6.9.7 Industrial Energy Management Programs

1. Australia: Energy Efficiency Opportunities (EEO) Program mandatory for corporations using more than 0.5 PJ of energy per year. Expansion of program announced.
2. Canada: EcoEnergy Efficiency for Industry Program which supports the early implementation of the new International Standard Organization 50001 (ISO 50001) Energy Management Systems standard.
3. EU members: Voluntary agreements in place in Belgium, Denmark, Finland, Ireland, the Netherlands, and Sweden.
4. Japan: Energy managers required for large industries.
5. South Korea: Voluntary energy saving through partnership program, and energy management diagnostic tools, training for energy managers and other support.
6. The USA: Voluntary energy management certification program, implementation of ISO 50001. Technical support programs in place, especially for small and medium enterprises (SMEs).

6.9.8 Industrial MEPS for Electric Motors

1. Australia: IE2 (high efficiency) MEPS for 3-phase industrial electric motors.
2. EU members: IE3 (premium efficiency) MEPS for 3-phase induction motors <7.5 KW by 2015; all IE3 (IE2 + Variable Speed Drive) in 2017.
3. Japan: Adding 3-phase induction MEPS to Top Runner program.
4. South Korea: IE2 3-phase electric motors.
5. New Zealand: MEPS are in place at level II standards. Investigation underway to advance to level III.
6. The U.S.: IE3 (premium efficiency) MEPS for 3-phase induction motors.

6.9.9 Energy Utilities

Energy efficiency obligation schemes

1. Australia: The States/Territories of NSW/ACT, SA and Victoria have implemented white certificates schemes. The legislation passed for Energy Efficiency Opportunities (EEO) program extension to generators in July 2012.
2. Canada: Some provincial jurisdictions enforce demand side management (DSM) targets.
3. EU members: White certificate schemes in place in Denmark, France, Italy, and UK. Voluntary obligations scheme introduced in Ireland.
4. Japan: Benchmark scheme for power plants.

5. South Korea: Energy utilities forced to submit DSM investment plan.
6. New Zealand: A levy on electricity sales funds a government electricity efficiency improvement program.
7. The USA: Twenty-four states, representing well over 50 % of the US population and energy demand, have placed energy efficiency resource obligations on their regulated utilities.

6.10 Summary

Development and implementation of energy efficiency policies are highly correlated to energy prices (particularly oil and natural gas prices), increasing energy demand, and environment concerns. Almost all countries commenced energy efficiency policies after the two oil shocks in the 1970s. Gradually realizing that energy efficiency can be used as a fuel, energy efficiency policy makers never stop expanding the potential of energy efficiency.

Increasingly, energy efficiency policies are becoming very important part of climate change mitigation and local pollution mitigation policies. In China, for example, energy efficiency polices have forced to shut down many inefficient and carbon intensive power plants and industrial facilities.

Energy efficiency polices have successfully removed many market barriers. For example, to overcome the barrier of customer inertial behavior in using inefficient energy devices, the governments of Australia, China, some states in the USA, the EU, and many other countries used their energy policies to ban the production and distribution of incandescent lamps and provide massive incentives to customers who replace their inefficient refrigerators and other appliances.

Monitoring, reporting, and evaluation of the effectiveness of energy efficiency policies may be expensive and may take a long time, but it is necessary to evaluate government policies in order to make these policies more effective.

Energy efficiency policies should effectively fit individual countries' economic and technological conditions. Some energy policy, such as energy-efficient lighting policy, can widely fit almost all countries; but some other policy, such as heavy-duty vehicles standards, had been only adopted by Japan by April 2014. An effective energy efficiency policy should have direct influence on targeted provinces, states, cities, companies, entrepreneurs, and households.

References

APEC (2013) Peer review on energy efficiency in Malaysia, draft final report. Report for the APEC Energy Working Group. http://www.ewg.apec.org/documents/9b_Malaysia%20PREE%20Report_Final%20Draft.pdf

Camp RC (1989) Benchmarking: the search for industry best practices that lead to superior performance. ASQC Quality Press, Milwaukee

Crossley D (2013) Energy efficiency in China, RAP. http://www.raponline.org/search Cited on 3 Jan 2013

DSIRE—Database of State Renewable Energy and Energy Efficiency Incentives (2013) Energy efficiency incentives and regulations search page. http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US04R&State=federal&currentpageid=1&ee=1&re=0. Accessed in Jan 2013

Doris E, Cochran J, Vorum M (2009) Energy efficiency policy in the United States: overview of trends at different levels of government technical report NREL/TP-6A2-46532 December

IEA— International Energy Agency (2012) World Energy Outlook 2012, OECD/IEA, International Energy Agency, 9 rue de la Fédération, 75739 Paris Cedex 15, France

IEA—International Energy Agency (2013) World energy outlook, Paris. http://www.worldenergyoutlook.org/publications/weo-2013/

Jollands N, Waide P, Ellis M, Onoda T, Laustsen J, Tanaka K, T'Serclaes P, Barnsley I, Bradley R, Meier A (2010) The 25 IEA energy efficiency policy recommendations to the G8 Gleneagles Plan of Action. Energy Policy 38(11):6409–6418

Klessmann C, Graus W, Harmelink M, Geurts F (2007) Making energy-efficiency happen: from potential to reality. WWF International, Utrecht

Pepco (2014) Appliance rebate program—clothes washers. https://homeenergysavings.pepco.com/appliance-rebate-program/overview/clothes-washers Cited 8 Nov 2014

Phylipsen G, Nyboer J, Oliver J, Pape A, Worrell E, Blok K (1996) Methodologies for international comparisons of industrial energy efficiency. In: Proceedings of workshop on methodologies for international comparisons of industrial energy efficiency, Vancouver, BC, Canada, pp 1–33

UNF—United Nations Foundation (2007) Realizing the potential of energy efficiency—targets, policies, and measures for G8 countries. Expert Report of the United Nations Foundation, Washington, D.C.

Yang (2013) Closing the gap: GEF experiences in global energy efficiency, Springer. http://www.springer.com/engineering/energy+technology/book/978-1-4471-4515-8

Chapter 7
Energy Efficiency Cost-Effectiveness Test

Abstract Cost-effectiveness for energy efficiency projects can be undertaken from at least five perspectives: participants (energy end users), energy utility, total customer of the utility, total customer and the utility together, and the society or the economy. The mathematical formulas to calculate the costs and benefits for the five tests are very similar, but some of the parameters have different meanings. In all cases, it is necessary to calculate net present value of a project over lifetime. This chapter presents basic formula for energy efficiency cost-effectiveness test from the perspective of participants or energy end users.

7.1 Introduction

Cost-effectiveness is defined as an approach to comparing the benefits against the costs of an investment. If the benefits reach certain threshold of the investor, the investment is considered as effective. In 1974, the Warren-Alquist Act (bill SB 1575) established the California Energy Commission and specified cost-effectiveness as a leading resource planning principle, which became a foundation for energy efficiency project cost-benefit analysis. In 1983, California's Standard Practice for Cost-Benefit Analysis of Conservation and Load Management Programs Manual developed five cost-effectiveness analyses for evaluating energy efficiency programs and projects. These analyses, with minor updates, continue to be used today and are the principal analytic approaches used for evaluating energy efficiency programs in the USA and many other countries (U.S. EPA 2008). All approaches in cost-effectiveness analysis use the same fundamental methodology in comparing costs and benefits, although each approach is designed to address different questions regarding the cost-effectiveness of DSM and energy efficiency programs from different perspectives of project stakeholders.

This chapter examines a standard cost-effectiveness analysis methodology from the perspective of participants, which is mostly used to assess the cost-effectiveness of energy efficiency projects and programs. It also discusses details on the input

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_7

data of the formula. The approaches described below consist of (1) presenting the mathematical formulas for the analysis, (2) specifying the components of benefits and costs for the test, (3) illustrating data required to calculate the benefits and costs in the test, and (4) showing applications on using the analysis results in energy efficiency policy development. More detailed information is available in CA (2010).

7.2 Methodology of Participant Analysis

7.2.1 *Significance of the Analysis*

The participant analysis is the measure of the quantifiable benefits and costs to the participants in an energy efficiency project or a program. This method is the "first tool" for customers to decide whether they would like to invest their capital in energy efficiency projects or programs. Customers will not invest in energy efficiency if their investment cannot be recovered during the project lifetime period.

To energy companies or utilities, this analysis result is also very useful for voluntary programs as an indication of potential participation rate. For energy efficiency programs that involve a utility incentive, the participant analysis can be used for program design considerations such as the minimum incentive level, whether incentives are really needed to induce participation, and whether changes in incentive levels will induce the desired amount of participation. The analysis results are useful for program penetration and for the development of program participation goals. For fuel substitution programs, the participant analysis can be used to determine whether the program participation will be in the long-run best interest of the customer.

7.2.2 *Formulas*

The results of this analysis are primarily expressed in three ways: (1) the NPV, (2) benefit–cost ratio (BCR), and (3) discounted payback period (DPP). The formulas of the participant analysis can be mathematically expressed as follows:

$$B = \sum_{t=1}^{n} \frac{\mathrm{BR}_t + \mathrm{TC}_t + \mathrm{INC}_t + \mathrm{AB}_{at} + \mathrm{PA}_{at} + \mathrm{OB}_t}{(1+d)^{t-1}} \tag{7.1}$$

$$C = \sum_{t=1}^{n} \frac{\mathrm{I}_t + \mathrm{PC}_t + \mathrm{BI}_t + \mathrm{OC}_t}{(1+d)^{t-1}} \tag{7.2}$$

$$\mathrm{NPV} = B - C \tag{7.3}$$

$$\mathrm{BCR} = \frac{B}{C} \tag{7.4}$$

$$\sum_{t=1}^{n} \frac{\mathrm{BR}_t + \mathrm{TC}_t + \mathrm{INC}_t + \mathrm{AB}_{at} + \mathrm{PA}_{at} + \mathrm{OB}_t}{(1+\mathrm{IRR})^{t-1}} = \sum_{t=1}^{n} \frac{\mathrm{I}_t + \mathrm{PC}_t + \mathrm{BI}_t + \mathrm{OC}_t}{(1+\mathrm{IRR})^{t-1}} \tag{7.5}$$

$$\mathrm{DPP} = \frac{\sum_{t=1}^{n} \frac{I_t}{(1+d)^{t-1}}}{\frac{B}{n}} \tag{7.6}$$

$$\mathrm{PP} = \frac{\sum_{t=1}^{n} I_t}{\frac{1}{n}\sum_{t=1}^{n} \mathrm{BR}_t + \mathrm{TC}_t + \mathrm{INC}_t + \mathrm{AB}_{at} + \mathrm{PA}_{at} + \mathrm{OB}_t} \tag{7.7}$$

where

B Present value of project benefits including

- BR_t Energy bill reductions in year t
- TC_t Tax credits in year t
- INC_t Incentives paid to the participant by the sponsoring utility or the government in year t
- AB_{at} Avoided bill from alternate fuel in year t
- PA_{at} Participant avoided costs in year t for alternate fuel devices (costs of devices not chosen)
- OB_t Other benefits such as carbon credit benefits in year t
- d Discount rate of the project
- n Economic lifetime of the project in number of years

C Present value of project costs including

- I_t Investment of capital by the participant in year t
- PC_t Operation costs of the participant including ongoing operation and maintenance costs such as fuel costs, removal costs (less salvage value), taxes, and value of the customer's time in arranging for installation
- BI_t Energy bill increases in year t
- OC_t Any other costs in year t

NPV Project net present value

BCR benefit–cost ratio

DPP Discounted payback period

IRR Internal rate of return

7.2.3 Parameters and Indictors of the Formulas

7.2.3.1 Present Value of Project Benefits (B)

In the case of energy savings projects or programs, the benefits of participation in an energy efficiency program include the reduction in the customer's utility bills, any incentive paid by the utility or other third parties, and any federal, state, or local tax credit received. The reductions to the utility bills should be calculated using the actual retail rates that would have been charged for the energy service provided (electric demand or energy or gas). Saving estimates should be based on gross savings, as opposed to net energy savings. In the case of fuel substitution programs, benefits to the participant also include the avoided capital and operating costs of the equipment/appliance which are not chosen. Present value of project benefits refers to the discounted sum of benefits associated with a project (Eq. 7.1).

7.2.3.2 Present Value of Project Costs (C)

The program or project costs to participant are all out-of-pocket expenses incurred as a result of participating in a program, plus any increases in the customer's utility bills. The out-of-pocket expenses consist of the cost of any equipment or materials purchased, including sales tax and installation, any ongoing operation and maintenance costs, any removal costs (less salvage value), and the value of the customer's time in arranging for the installation of the measure. Present value of project costs refers to the discounted sum, or present value, of a stream of all costs associated with a project (Eq. 7.2).

7.2.3.3 Net Present Value

A significant driver of overall cost-effectiveness analysis of energy efficiency is to calculate the NPV of the discounted and accumulated costs and benefits. The NPV is used in capital budgeting for customers to judge the profitability of an investment in a project. The NPV is defined as the difference between the present value of discounted cash inflows (the project benefits) and the present value of discounted cash outflows (the project costs). The NPV gives the net dollar benefits of the project to an average participant or to all participants discounted over some specified time period. A positive NPV value indicates that the project is beneficial to the investors and that the project might be accepted. A negative NPV shows that the project is not beneficial to the investors and that the project may probably be rejected (Eq. 7.3).

7.2.3.4 Benefit–cost ratio (BCR)

The BCR is the ratio of the total discounted benefits of a project or program to the total discounted costs over some specified time period. The benefit–cost ratio gives a measure of a rough rate of return for the program to the participants and is also an indication of risk. A benefit–cost ratio above one indicates a beneficial program (Eq. 7.4).

7.2.3.5 Internal Rate of Return (IRR)

An IRR is a discount rate that is used in capital budgeting to make the project NPV zero. If the IRR of a project is greater than the capital cost paid by an individual or a firm, the project may become a candidate project for investment from the perspective of the individual or the firm. IRRs can be used to rank several prospective projects which an investor is considering. If all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first. An IRR can be thought as the growth rate of a project. While the actual rate of return that a given project ends up generating will often differ from its estimated IRR rate, a project with a substantially higher IRR value than other available options would still provide a much better chance of strong growth (Eq. 7.5).

7.2.3.6 Discounted Payback Period (DPP)

The DPP is a capital budgeting procedure used to determine the profitability of a project. In contrast to an NPV analysis, which provides the overall value of a project, a DPP gives the number of years it takes to break even from undertaking the initial expenditure. Future cash flows are discounted to time "zero." This procedure is similar to a payback period; however, the payback period only measures how long it takes for the initial cash outflow to be paid back, ignoring the time value of money. Projects that have a negative net present value will not have a discounted payback period, because the initial outlay will never be fully repaid. This is in contrast to a payback period where the gross inflow of future cash flows could be greater than the initial outflow, but when the inflows are discounted, the NPV is negative (Investopedia 2014) (Eq. 7.6).

7.2.3.7 Payback Period (PP)

A PP is the length of time required to recover the cost of an investment. The payback period is an important determinant of the feasibility of the project. Longer payback periods are typically not desirable for investment positions. If all other things are equal, the better investment is the one with the shorter payback period. For example, if a project capital investment is US$1,000,000 and the project will earn US$200,000 annually, the payback period will be 5 years (US$1,000,000/US$200,000). There are three main issues with the payback period method. First, it does not account any benefits that occur after the payback period. Second, it does not account the value of time. Third, it does not measure profit of the project (Eq. 7.7).

7.2.3.8 Discount Rate (D)

Economically, a dollar has more value today than tomorrow. When adding dollar values that occurred in different dates or years, a discount rate must be used. The higher the discount rate, the lower value the future dollar. Since costs typically occur upfront and savings occur over time, the lower the discount rate, the more likely positive the NPV. The discount rate is associated with customers' opportunity cost of capital, and the rate can be different among customers or participants from the same community.

Three kinds of discount rates are usually used in the energy efficiency projects, depending on different customers. For a household customer, this rate is the debt cost that a private individual would pay to finance an energy efficiency investment. It is typically the average interest in local commercial banks, assuming that the household gets a loan from the local bank to finance the energy project. Based on the historical consumer loan market environment, a typical value may be in the 8–10 % range (though a credit card rate might be much higher). For a business firm, the discount rate is the firm's weighted average cost of capital. In historical capital market environment, a typical value would be in the 10–12 % range—though it can be as high as 20 %, depending on the firm's credit worthiness and debt-equity structure. Businesses may also assume higher discount rates if they perceive several attractive investment opportunities as competing for their limited capital dollars. Commercial and industrial customers can have payback thresholds of 2 years or less, implying a discount rate well in excess of 20 %.

7.3 Application of the Cost-Effective Results

In energy efficiency project analysis, the values of indicators of NPVs, BCRs, IRRs, DPPs, and PPs are widely used by different investors depending on their preferences. Generally, financiers or economists prefer to calculate NPVs, while firm managers prefer to use BCRs and IRRs and engineers prefer to use DPPs or PPs. These indicators can all show whether a project is cost-effective. For example, if the NPV of a project is positive, the BCR will be greater than one, the IRR will be greater than the firm's rate of capital cost, and the DPP and PP in this project will likely be shorter than other projects. The cost-effectiveness analysis of a project helps determine the financial viability and sustainability of the project.

Another area of growing interest in the application of cost-effectiveness analysis is in establishing incentive mechanisms for utility efficiency programs. There exist two natural disincentives for utilities to invest in energy efficiency programs. First, energy efficiency reduces sales, which can affect utility earnings. Second, utilities make money through a return on their capital investments or rate base. To address the reduced earnings from energy efficiency, countries are increasingly exploring incentive mechanisms that allow a utility to earn a return on energy efficiency expenditures. The intent is to give the utility an equal (or greater) financial incentive to invest in energy efficiency as compared to traditional utility infrastructure.

The results of cost-effectiveness analysis are increasingly being used as a metric to measure the incentive payment to the utility, based on the performance of the energy efficiency program. When the cost-effectiveness analyses are used in the payment of shareholder incentives, there will be additional scrutiny on the input assumptions and key drivers in the calculation. With this additional pressure, transparency and stakeholder review of the methodology becomes more important. Finally, the use of cost-effectiveness analyses and their weights must be considered with care to align the utility objectives with the goals of the energy efficiency policy.

It should be noted that none of the participant analysis results (discounted payback, net present value, or cost–benefit ratio) can accurately capture the complexities and diversity of customer decision-making processes for energy efficiency investments. Customer attitudes and behavior toward energy efficiency may continue to be the major decision factors beyond interpretations of participant analysis results. The participant analysis results play only a supportive role in any assessment of energy efficiency projects.

7.4 Summary

Cost-effectiveness analysis on energy efficiency projects or programs is an approach used by investors to test whether they should invest their capital. While undertaking such an analysis, it is important to count all costs and benefits of the project as cash flow throughout the lifetime of the project from the perspective of the investor. Time has value for any project development and investment, and time value of the project can be captured by using discount rate in the analysis. The most commonly used indicators for such analysis include project NPV, BCR, IRR, DPP, and PP. These indicators are widely used by different investors depending on investors' preferences. If a project NPV is positive, the project investment may be considered as cost-effective.

References

CA (2010) California standard practice manual economic analysis of demand-side programs and projects, Oct 2001. http://www.energy.ca.gov/greenbuilding/documents/background/07-J_CPUC_STANDARD_PRACTICE_MANUAL.PDF

Investopedia (2014) Discounted payback period. http://www.investopedia.com/terms/d/discounted-payback-period.asp. Cited on 11 Jan 2014

U.S. EPA (2008) Understanding cost-effectiveness of energy efficiency programs: best practices, technical methods, and emerging issues for policy-makers, a resource of the national action plan for energy efficiency, Nov. http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf. Cited on 14 Jan 2014

Chapter 8
Energy Efficiency Project Finance

Abstract Lack of financing mechanism in the market is a barrier to energy efficiency in many developing countries. Government policy can create effective financial mechanisms in the market to unlock this barrier. These effective financial mechanisms can be in the forms of rebates, grants, or low-interest loans for energy efficiency improvements, direct income tax deductions for individuals and businesses, and exemptions or reduced sales tax on eligible products. Incentives offered by national governments are generally in the form of tax incentives. Utilities can rebate energy-efficient appliances and equipment for any energy end users in the system, which facilitates energy efficiency investments. Private sector-based ESCOs and individual energy end users or customers are beneficiaries of governments' and utilities' financial mechanisms.

8.1 Introduction

Energy efficiency project financing is defined as a financial structure that relies primarily on the project's cash flow for repayment, with the project's assets, rights, and interests held as secondary security or collateral (Investopedia 2014). There are two basic types of energy efficiency financing: (1) loans, debt, and equity financing and (2) off-balance-sheet financing. In the first type, capital investment in projects appears on the balance sheet of companies, which likely increases the debt/equity ratio of the company. For example, equity financing involves the sale of common equity, or other equity or quasi-equity instruments such as preferred stock, convertible preferred stock, and equity units that include common shares and warrants. After such sales, the equity assets will be taken out from the firm's balance sheet and the new capital equipment purchased will also be shown in the balance sheet. In the second type, all equity will not appear in the company's balance sheet and no new capital equipment purchased. Examples of off-balance-sheet financing include joint ventures, research and development partnerships, and operating leases, rather than purchases of capital equipment. Operating leases for energy-efficient

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_8

equipment is one of the most common forms of off-balance-sheet financing. In these cases, the asset itself is kept on the lessor's balance sheet, and the lessee reports only the required rental expense for use of the asset. Energy efficiency project finance therefore is especially attractive to the private sector because private investors can fund major projects off balance sheet to keep their debt to equity ratios low, especially if the inclusion of a large expenditure would break negative debt covenants. A large number of innovative financing models are emerging in the energy market on the basis of the two fundamental types.

Innovations and the development of new financing models to remove barriers are accelerating energy efficiency investments. National government policies, utility incentives, in concert with innovative financing methods, are mobilizing capital for energy efficiency projects and mitigating project-level risks. As a result, hundreds of billion dollars in project opportunities worldwide are being driven by renewed interest of investors.

The increased energy efficiency finance strategies also encourage more rapid adoption of cutting-edge technologies related to energy efficiency. These includes smart grid hardware and software, energy information management and sensor controls, demand response, energy storage, super-efficient lighting, and other building mechanical and electrical equipment, as well as distributed renewable generation technologies. These technologies, in turn, can facilitate more solutions to existing challenges in implementing energy efficiency projects on a larger scale.

More and more energy efficiency finance strategies also involve multiple financial parties, or financiers in the market for energy efficiency projects. These financiers can be grouped into (1) multilateral governments; (2) national, provincial, state, municipal governments; (3) energy utilities (corporatized government entities); (4) multilateral banks and international financiers; (5) UN agencies and climate change convention-related financial mechanisms; (6) commercial banks (the private sector); (7) ESCOs (the private sector); and (8) individual end users (the private sector). The first four groups mainly provide or create macro-financial incentives schemes and along with their energy efficiency policies and programs, and the last three groups focus on micro-level to finance individual energy efficiency projects.

Financial incentives from the government and energy utilities are an important instrument for spurring investment in energy-efficient technologies and energy efficiency services. The incorporation of a financial incentive can make energy efficiency investments more alluring for private and public entities, particularly by lowering inhibitive upfront costs. Financial incentives also complement other efficiency policies such as appliance standards and energy codes, overcoming market barriers for cost-effective technologies.

Although a successful energy efficiency financing mechanism depends on join efforts of all these financiers, the private sector and the end users play the most important role in sustainable investment in energy efficiency. The private sector-based ESCO market for energy efficiency services in the industrial sector and commercial and institutional buildings has enjoyed greater success recently in the USA, Europe, China, and many other countries over the past decades. In the private sector-based ESCO market, energy efficiency project financing is a key to the success at the micro-level for individual project development and financing.

This chapter provides an overview of four major energy efficiency finance models that are widely used in the energy efficiency market. It also provides an analysis of the main challenges, legal considerations, and opportunities associated with scaling up and deploying these models. While many other energy efficiency finance options also exist, these four models are among those attracting significant interest from both private and public sector stakeholders worldwide, particularly in developing countries. A number of examples of project financing for each of these models are also presented.

8.2 Financing Models

Four financing models are widely used in energy efficiency markets, although various other models are also available. Three of the four models directly involve public–private partnership (PPP) financing, and the last one is mainly applied in the private sector financing.

A PPP financing model is defined as a mechanism to use joint public–private approaches to encouraging and promoting private sector investment in energy efficiency projects. The PPP uses public policies, regulations, or financing to leverage private sector financing for energy efficiency projects. Characteristics of PPPs for financing energy efficiency include the following: (1) a contractual relationship, or less formal agreement, between a public entity and a private organization; (2) allocation of risks between the public and private partners, consistent with their willingness and ability to mitigate risks, to encourage the private partner to mobilize financing; (3) mobilization of increased financing for energy efficiency projects; and (4) payments to the private sector for delivering services to the public sector. Under such PPP models, the public sector can firstly develop policy and regulatory instruments to overcome the barriers and facilitate the scaling up of investments in energy efficiency projects. Then, commercial banks are necessary to sustain the scaling up of energy efficiency investments with attractive loan interest rates. The active participation of commercial banks and financial institutions is needed for the long-term growth and development of the market for delivering energy efficiency financing and implementation services. Afterward, the private sector is willing to apply for loans in energy efficiency investments, and the banks are willing to lend loans to the private sector. In energy efficiency markets, there are three basic PPP financing models: (1) dedicated credit lines; (2) risk-sharing facilities, and (3) energy saving performance contracts (ESPCs).

8.2.1 Dedicated Credit Lines

8.2.1.1 Definition of Dedicated Credit Lines

Dedicated credit lines are credit lines established by a public entity such as a government agency and/or donor organization to make a private sector organization such as a commercial bank or a financial institution capable of financing energy efficiency projects.

8.2.1.2 Objectives and Approaches of Dedicated Credit Lines

The objective of a dedicated credit line for energy efficiency financing is to mobilize commercial financing from local financial institutions (LFIs) for energy efficiency projects. The approach is to provide funding to the LFIs with government, international financial institutions (IFIs), or donor agency funds, such as GEF funds, so that the LFIs can then on-lend to project developers or implementers. A dedicated credit line is effective in overcoming the issues related to insufficient availability of funds for energy efficiency projects, because it leverages an increase in lending by the private partners or the LFIs for energy efficiency projects. It also addresses the issue of insufficient or nonexistent lending to energy efficiency projects due to the LFIs' lack of knowledge and understanding of the characteristics and benefits of the projects. By providing funds to the LFIs, generally at a lower interest rate than the market rates, the public partner gives an incentive to the private sector LFIs to on-lend funds for energy efficiency projects. Because the on-lending is at a higher interest rate, the LFI can earn a profit on the loan transactions. The agreement between the public and private partners generally requires the LFI to co-finance the loans, thereby leveraging and increasing the available amount of capital.

The credit line generally also includes technical assistance to the participating LFIs to enhance technical capacity of the LFIs. This financing model can scale up energy efficiency financing and lending; strengthen the participating bank's capacity in identifying investment opportunities and project risks and managing them; and assist the participating bank in establishing a new business in energy efficiency and other low carbon energy.

8.2.1.3 Structure of Dedicated Credit Lines

In a dedicated credit line, a public partner provides a credit line at low interest to private partners, such as LFIs (Fig. 8.1). The agreement between the public and private partners identifies the types of projects eligible for financing with the credit line. The agreement also specifies the requirements for the LFIs to co-finance the projects to increase the total size of the loan fund available. Normally, the LFIs put more capital than the public sector in such a partnership.

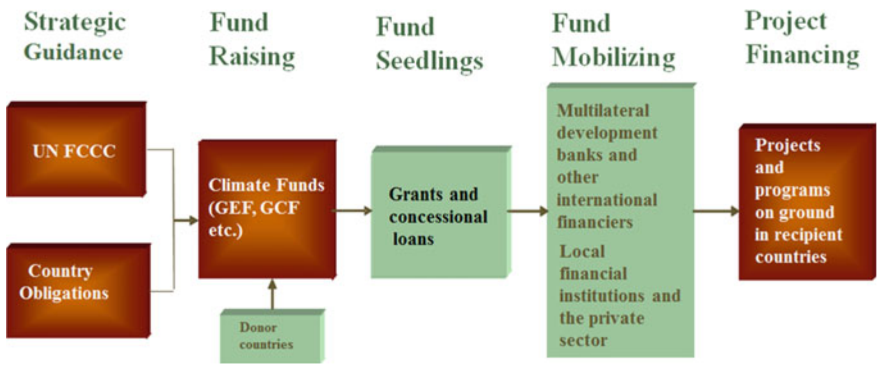


Fig. 8.1 Structure of dedicated credit line financing. *Source* Authors developed

The LFI generally charges a fee for loan processing and may charge market rates for its funds, but the total interest cost to the LFI for financing projects is generally lower than the market interest rate due to the availability of the low-interest funds from the public partner. The LFI, therefore, may be able to provide loans for energy efficiency projects at a lower-than-market interest rate. Some dedicated credit lines, however, require LFIs to on-lend the funds at market interest rates to avoid any possible market distortions.

In addition to IFIs and LFIs, project developers are usually involved in financing. They may put some cash or equity in projects. As a result, the project financing consists of three parts: (1) government or IFI's or donor agency funds, (2) LFIs funds, and (3) project developers' funds. For example, in the case of the China Energy Efficiency Financing (CHEEF) program, the local commercial banks matched the donor/government funds on a 1:1 basis and required a 30 % equity investment from project developers or project owners for each project. The public partner is able to obtain a leverage ratio of about 286 % in terms of the funds provided to the total investment in energy efficiency projects (IIP 2014).

8.2.2 *Risk-Sharing Facilities*

8.2.2.1 Definition of Risk-Sharing Facilities

Risk-sharing facilities are partial risk or partial credit guarantee programs established by a public entity, such as a government agency and/or donor organization, to reduce the risk of energy efficiency project financing for the private sector. By sharing the risk through a guarantee mechanism, these facilities thereby enable increased private sector lending to energy efficiency projects. They address the perception of LFIs that energy efficiency projects are more risky than their conventional lending. Under the risk-sharing facilities, the public agency provides a partial guarantee that covers a portion of the loss due to loan defaults. By sharing the risk, the public partner reduces the risk to private sector LFIs, thereby motivating LFIs to increase its lending to energy efficiency projects (Mostert 2010).

8.2.2.2 Objectives and Approaches of Risk-Sharing Facilities

One of the barriers to energy efficiency financing in the energy market is LFIs' perception that energy efficiency projects are inherently more risky than traditional investments. The objective of risk-sharing facilities is to reduce the risk by providing participating LFIs with partial risk coverage in extending loans for energy efficiency projects. The risk-sharing facility directly facilitates increased financing of energy efficiency projects by overcoming the barriers to structuring the transactions and by building the capacity of LFIs to finance energy efficiency projects on a commercially sustainable basis. The most common examples of risk-sharing facilities are publicly backed partial risk guarantees or partial credit guarantees (Mostert 2010).

Providers of risk-sharing facilities assist energy efficiency project implementers by (1) providing access to finance from commercial LFIs; (2) reducing the cost of capital by reducing the risk faced by the lender; (3) expanding the loan tenor or grace period to match project cash flows; and (4) helping create a long-term sustainable market for financing of energy efficiency projects. Risk-sharing facilities also provide technical assistance to lenders. They support LFIs to deliver energy efficiency financing services and facilitate project developers to prepare projects and programs for investment.

8.2.2.3 Structure of the Risk-Sharing Mechanism

In the basic structure of a risk-sharing program, a public agency, either a government or donor agency, signs a guarantee facility agreement (GFA) with participating LFIs to cover a portion of their potential losses. Under the GFA, the public agency provides a partial guarantee, covering loan loss from default. Although the actual amount of the loss covered by the guarantee may vary, typically the guarantee is for a 50–50 ("pari passu") sharing of the losses between the LFI and the public agency.

Participating LFIs sign agreements with project developers, specifying loan targets and conditions. LFIs are responsible for conducting due diligence and processing the loans, and the project developers repay loans to the LFIs. The public agency may specify certain terms and conditions for the project appraisal. The public agency generally approves each project (or project portfolio) for each LFI. In case of loan default, the guarantee facility covers the specified portion of the loss.

The risk-sharing facility may offer individual project guarantees or portfolio guarantees. In the case of individual project guarantees, the public agency is involved in each individual transaction, appraising the eligibility of the applicant borrower for the guarantee in parallel with the LFI's due diligence to determine eligibility for a loan. In the case of a portfolio guarantee, the public agency covers all loans by the LFI to a class of borrowers. The LFI has the responsibility for project appraisal and due diligence, and therefore, the public agency does not provide 100 % guarantee to cover loan losses. Thus, risk-sharing programs are designed to provide partial risk guarantee facilities.

There are three types of partial guarantees. The first is pro-rata guarantee where the loss is shared between the LFI and the public agency according to a pre-specified formula. Typically, the risk share of the public agency is between 50 and 80 %. The second is first-loss guarantee, which pays for losses from the first losses incurred until the specified amount of the first-loss facility is exhausted; the lender incurs losses only when the total loan loss exceeds the first-loss guarantee amount. By covering a large share of first losses and defining first losses to be a reasonable proportion of the loan portfolio (usually higher than the estimated default/loss rate), a first-loss portfolio guarantee can provide very meaningful risk coverage to the lender. The third is second-loss guarantee that pays for losses that exceed the non-guaranteed portion of the loan. The main idea of such a guarantee is to cover incremental losses beyond the LFI's normal loss rate. For example, suppose the LFI has an average loss rate of 1 % of its loan portfolio. When asked to move into a new business segment that it perceives to have higher risk (such as energy efficiency loans), the LFI would expect the average loss rate to be higher.

8.2.3 Energy Saving Performance Contracts

8.2.3.1 Definition of Energy Saving Performance Contracts

Energy Saving Performance Contracts (ESPCs) are public sector initiatives in the form of legislation or regulation established by government agencies to facilitate the implementation by ESCOs of performance-based contracts using private sector financing. The concept of performance contracting was originated in France in the 1950s, developed in North America during the 1980s and 1990s, and successfully implemented in many European countries, Japan, and South Korea (Singh et al. 2010). ESPCs address a number of barriers to implement energy efficiency projects in the public sector. Under the ESPC concept, ESCOs or other types of energy service providers offer a broad range of services, including providing or arranging commercial financing, to public agencies, industries, housing associations, etc., under a performance-based agreement, in which guarantees are provided for the energy savings to be achieved. In the context of PPPs, ESPCs are involved in implementation of energy efficiency in the public sector. The public agency makes payments to the ESCO only upon the satisfaction of the guarantees, thereby eliminating much of the technical and performance risk from the public agency.

8.2.3.2 Objectives and Approaches of Energy Saving Performance Contracts

The objective of ESPCs is for the public partner (the government) to provide investors with an effective tool overcoming financing barriers in the energy market. The public partner creates the enabling environment for an ESPC, including legislative and regulatory changes needed to facilitate performance contracting projects in the public sector. The ESPC mobilizes ESCOs to implement energy efficiency projects on a large scale using the performance contracting approach to implementing energy efficiency projects in public facilities. The customer can also directly engage an ESCO to design and implement an energy efficiency improvement project with its remuneration connected in one way or another to the performance of the project. Generally, some form of performance guarantee such as a guarantee of energy savings is provided by the service provider (IEA 2010).

The service provider can offer a range of services to the customer, such as an energy auditing, project identification and design, equipment procurement, installation and commissioning, measurement and verification, training, and operations and maintenance. Generally, the service provider also provides or arranges the financing for the energy efficiency project (Singh et al. 2010). In this way, private sector expertise and capital can be deployed, allowing technical risks to be transferred away from the customer, facilitating equipment procurement, and offering flexible financing options. More importantly, the project development and implementation can be outsourced to an entity that has the skills and incentives to overcome any short-term barriers and help realize the significant energy efficiency potential.

The public partner has two roles in an ESPC. The first is to create the enabling environment through legislative and regulatory changes that facilitate the implementation of the ESPC, and the second is to provide the public facilities in which the private sector will implement energy efficiency projects using the ESPC. The basic features of ESPCs offered by an energy services provider (ESP) or an ESCO are numerous (SRC 2005). ESCOs can be an important institutional mechanism for the delivery of energy efficiency investments. In recent years, many established ESCOs have become active, and new ESCOs have been created in developing countries (Motiva 2005; Hansen et al. 2009). ESCOs strive to develop and implement energy efficiency projects for energy users around the world. ESPCs can cover a complete energy efficiency service, including design, engineering, construction, commissioning, and operation and maintenance of the energy efficiency measures, as well as training and measurement and verification of the resulting energy and cost savings. ESPC services also include providing or arranging financing. Often a link exists between payments to the ESCO and the project performance; customers pay for the energy services from a portion of actual energy cost savings achieved.

8.2.3.3 Structures of Energy Saving Performance Contracts

Although many different variations exist in the specific approaches to ESPCs, they have three basic structural agreements: shared savings, guaranteed savings, and energy supply contracting (Singh et al. 2010). In all three types of agreements, the ESCO provides a wide range of implementation services and generates energy and cost savings. The differences are in the manner in which the project is financed, payments are made from the host facility to the ESCO, and energy and cost savings are allocated between the ESCO and the host facility.

In the shared savings contract model (Fig. 8.2), ESCOs provide the bulk of project financing and are compensated for their investment and services by their client from a portion of the energy cost savings resulting from the project. The assets created by the project are owned by the ESCO until contract completion, when they are transferred to the client, usually for no charge. Usually and conservatively, the minimum energy cost savings stream from the project is estimated by the ESCO in the contract and acknowledged by the client. In most cases, contracts provide for payment streams to the ESCOs based on an agreed percentage share of the agreed estimated minimum cost savings scenario, as long as project savings monitoring arrangements verify that at least the agreed level of energy savings has materialized with normal asset operation. Any additional savings are usually given to the clients. As long as the project is implemented with the basic results originally expected, these contracts typically result in a predictable payment stream. Although there are cases where payment streams vary every payment period, based on ongoing measurements of actual saving during the contract period, such cases are in the minority.

In a guaranteed savings agreement (Fig. 8.3), the customer provides the bulk of project financing and takes the loan on its own balance sheet. Assets generated belong to the client. In addition to design and implementation services, ESCOs guarantee certain performance parameters, such as efficiency, energy savings, cost savings, and/or other performance parameters, in the ESPC, which specifies the methods for monitoring and verification. Payments are made once the project

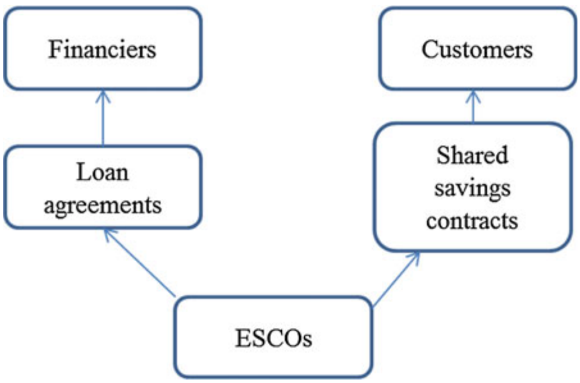


Fig. 8.2 Shared savings contract. *Source* Authors developed

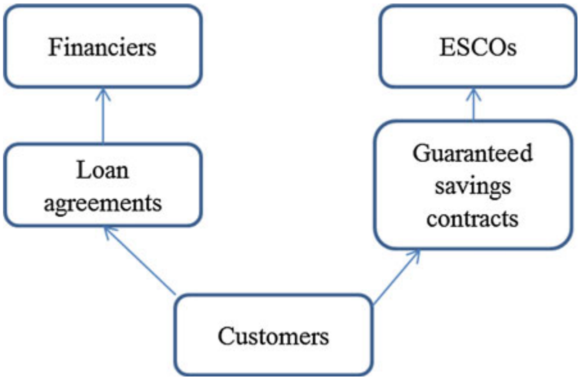


Fig. 8.3 Guaranteed savings contract. *Source* Authors developed

performance parameters have been confirmed. Failure to achieve the guaranteed energy savings amounts must have direct financing consequences to the ESCO.

In the outsourcing contract model (or energy supply contracting model), ESCOs finance and develop energy savings assets within the customer's facilities and operate these assets over an extended period for agreed compensation, which is linked in one way or another to the energy savings achieved. The ESCO owns the assets and transfers them to the client at the end of the contract, which may be 8–10 years. One common example is the development of on-site build-own-transfer power-generating facilities from an iron and steel production plant where there is waste energy. The ESCO invests in and operates a power generation facility, purchases the waste energy resource with a small fee or no charge, and sells the electricity to the plant at a rate well below the plant's purchasing price from the grid. In another case, ESCOs develop or purchase local district heating assets, undertake energy efficiency renovations and operate the system, and receive remuneration from the larger difference between heat sales revenue and fuel costs. In the latter case, ESCOs develop or purchase or lease the lighting and/or space-conditioning assets of a building, undertake energy efficiency renovations, operate the systems, pay the building's electricity bills, and charge the building owner or occupant fees for pre-defined lighting and/or space-conditioning services, at costs lower than before the involvement of the ESCOs (Fig. 8.4).

8.2.4 Leasing

8.2.4.1 Definition of Leasing

Advanced energy saving lighting, heating, ventilation, and air-conditioning systems can be expensive to customers, and leasing has become a key facilitator in the widening adoption of these technologies. Leasing is a form of access to finance based on a contract between two parties, the lessor and lessee. The lessor provides

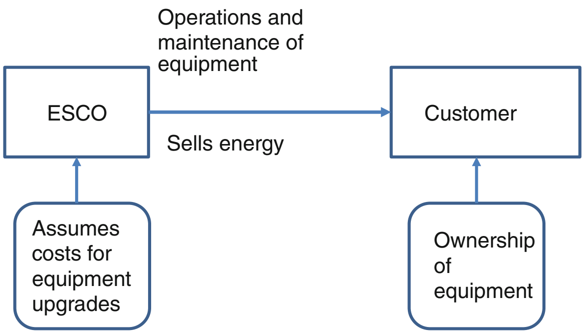


Fig. 8.4 Energy supply contracting model. *Note* At the end of the contract, the customer owns the equipment. *Source* Authors developed

an asset for use to the lessee for specific period of time in return for specified payments. Leasing is based on the proposition that income is earned through the use of assets rather than from ownership. It focuses on the lessee's ability to generate cash flow from business operations to serve the lease payment rather than on the balance sheet or on past credit history. With financial leasing, legal ownership remains with the lessor, while the lessee enjoys the right to economic usage of the asset. The asset could range from something as simple as an energy-efficient air conditioner to the development of an energy-efficient industrial production process.

As the leasing industry has adapted to evolving market conditions, the equipment for nearly any kind of energy efficiency upgrade can be leased. In addition, customers may include in their lease the "soft costs" associated with adopting them. These include installation, which often equals half of the total price tag, and operator training. This is important because efficient use of complex systems may require specialized operator skills and staffing requirements.

8.2.4.2 Objective of Leasing

The objective of leasing is to provide a powerful financial access for SMEs with much needed term-financing to invest in energy-efficient equipment. It enables SMEs to leverage an initial cash deposit with the inherent value of the asset being purchased acting as collateral. It is particularly effective in emerging economies where SMEs provide strong growth and employment opportunities, but lack of access to term-financing due to a limited development of capital markets and banking sector.

8.2.4.3 Rationale of Leasing

Leasing plays a critical role in bringing in small businesses into the formal financial system. Once informal businesses have access to lease financing, they begin building a history of financial transactions. When the appropriate credit information-sharing infrastructure is in place, banks and other financial institutions can access these records, better manage risks and start providing widespread financial services to these small businesses. With this new opportunity, small businesses also find additional incentives to join the formal sector.

Leasing is referred to as "creative financing" because payments can be tailored to a project's cash flow. This is in addition to any tax advantages inherent in the lease structure. Leasing "energy equipment" has become the fastest growing equipment sector within the leasing industry, because energy-efficient equipment can be financed out of the savings, resulting in a net positive cash flow for the user's organization.

8.2.4.4 Structures and Advantages of Leasing

Leasing has flexible repayment structures. Some businesses tend to be seasonal in terms of cash flow. With leasing, customers may be able to match their lease payments to their cash flows or budget requirements. Skip payments, annual payments, and deferred payments are all examples of lease structuring. For example, when a customer leases energy-efficient retrofit systems and equipment, he often can match lease payments to his energy savings and reduced maintenance costs. As a result, many such projects are cash flow neutral; some are actually cash flow positive. This provides a significant competitive edge if the customer operates commercial properties because he can translate savings on energy and maintenance into stabilized rents for his tenants.

Leasing has a fixed expense. With the uncertainty of interest rates and inflation, it is advantageous to lock-in long-term expenses—with today's dollars. In addition, customers have the opportunity to pay for the equipment from the savings realized through energy savings.

Leasing preserves existing lines of credit. Growing businesses generally have substantial credit needs to finance their development. By diversifying lending relationships, customers maximize their access to credit and they never "put all their eggs in one basket."

Leases are often very flexible in allowing for additions or upgrades to energy-efficient equipment, which enable customers to keep up and take advantage of evolving energy-efficient technologies. For many energy efficiency projects, one year of lost energy savings due to delayed upgrading of efficient equipment is usually greater than the entire cost of financing!

Leasing has tax advantages. A non-tax lease provides the benefits of ownership, so the value of the leased systems can be depreciated. In addition, any applicable federal or state energy tax incentives that the lessee is eligible for can be taken directly by the business. In this case, leasing provides 100 % write-off of the monthly lease payment. This is especially attractive to businesses subject to alternative minimum tax. A tax lease, on the other hand, allows the leasing company to take the tax benefits of ownership, though the leasing company typically passes a portion of these benefits on to the business in the form of a lower financing rate. In addition, under current tax regulations, the lease payments can be deducted as overhead, a business expense, on the business' tax return. This can be a critical way to optimize tax benefits if the business is not able to fully utilize them due to prior year tax losses.

8.2.5 Comparison of the Four Financial Models

Some features are common in the four financial models. For example, both dedicated credit lines and risk-sharing facilities include technical assistance and capacity building for the LFIs to increase their knowledge and understanding of energy efficiency projects, create greater interest on their part to increase lending to such projects, and help them identify and manage project risks and opportunities. Dedicated credit lines, risk-sharing facilities, and energy saving performance contracts are also not mutually exclusive. From time to time, a dedicated credit line or a risk-sharing facility is combined with policies and regulatory initiatives to facilitate ESPCs. Table 8.1 summarizes key features of the four financial models.

The application of energy efficiency financing structure depends on a number of important characteristics including the country context, the legislative and regulatory conditions, the existing energy services delivery infrastructure, and the maturity of the commercial financial market. The financial approaches discussed in this chapter are applicable in different market environments. They also represent different degrees of public and private financing approaches. Dedicated credit lines involve a greater degree of public sector financing where the government, IFIs, and donor agency provide funding to the private partners (LFIs). In risk-sharing facilities, the public sector provides a lesser amount of financing, focusing more on the risk guaranty provided. In the case of ESPCs, the public sector provides no direct financing, but creates the enabling legislative and regulatory frameworks and facilitates the negotiation of performance contracts between public agencies and ESCOs that lead to financing from the private sector. In leasing, the government does not provide direct funding, nor facilitate negotiation between the ESCOs and the customers, but only tax incentive policies.

Dedicated credit lines are most applicable when the commercial financial market is less mature and LFIs are not undertaking much financing of energy efficiency projects, due to lack of knowledge and understanding of the characteristics and benefits of energy efficiency projects and/or limited liquidity. Risk-sharing programs are useful when the commercial financing market is somewhat more mature, and LFIs are willing to consider financing energy efficiency but are concerned about the potential risks of such projects. The risk guarantees provided by the public partner help overcome this perception of high risk and encourage the LFIs to undertake financing of energy efficiency projects. With a mature commercial financing market, where LFIs have both the liquidity and the understanding and willingness to consider energy efficiency project financing, the ESPC mechanism

Table 8.1 Key features of the four financial models

Type of models	Brief description	Features				
		Role of government	Agreement between public and private entities	Allocation of risk between partners	Mobilization of private sector financing	Payment to the private sector for providing services
Dedicated credit lines	Mechanism under which governments or donors provide low-interest loans to LFIs to encourage them to offer subloans to implementers of energy efficiency projects	Direct financing	Loan agreement between partners	Project financing risk shared between partners	Private partner generally provides co-financing	LFI earns fee by on-lending funds at higher interest
Risk-sharing facilities	Mechanism where governments or multilateral banks offer guarantee product to absorb some energy efficiency project risks and encourage involvement of LFIs in energy efficiency financing by reducing their risk	Indirect financing	Guarantee Facility Agreement (GFA)	Public partner absorbs some financial risk	Risk reduction mobilizes additional private sector financing	LFI earns interest on additional loans mobilized
Energy saving performance contracts (ESPCs)	ESCO enters into term agreement with public agency to provide services, with payments contingent on demonstrated performance	No financing, but regulations	Energy Services Agreement	Performance risk generally borne by ESCO	ESCOs mobilize private sector financing	Performance-based payment to ESCO
Leasing	LFIs or ESCOs own and leases equipment to customers. ESCOs maintain equipment, Customer operates equipment	Tax incentives only	LFIs, ESCOs and customer agreements.	ESCOs bare equipment failure risk. Customers bare operation risks	ESCOs mobilize LFIs financing	Contract-based payment to ESCOs for equipment leasing

can be useful for scaling up the LFI financing. For small businesses, buildings, and households where various new and efficient energy technologies are needed in a large geographical scope and timely manner, leasing financial model can serve the needs of the customers.

8.3 Case Studies of Project Financing

8.3.1 Dedicated Credit Lines

Case studies under dedicated credit lines include: (1) the China Energy Efficiency Financing (CHEEF) program; (2) the Thailand Energy Efficiency Revolving Fund (TEERF); and (3) the KfW credit line to the Small Industries Development Bank of India (SIDBI) for energy efficiency projects in SMEs (KfW and SIDBI 2010).

8.3.1.1 China Energy Efficiency Financing Program

Using dedicated line credit to develop the CHEEF program, the World Bank encouraged Chinese banks to provide energy efficiency project loans (World Bank 2008). The line of credit was structured as a financial intermediary lending operation with a sovereign guarantee provided by the Ministry of Finance of China. In the program's first phase (called CHEEF I), the World Bank provided US$100 million each to two participating LFIs, Exim Bank and Huaxia Bank. The banks matched the World Bank funds on a 1:1 basis to increase the total size of the loan portfolio. In the program's second phase (CHEEF II), the World Bank worked with Minsheng Bank as the participating LFI.

8.3.1.2 Thailand Energy Efficiency Revolving Fund

The Royal Thai Government (RTG) established the Thailand Energy Efficiency Revolving Fund (TEERF) to stimulate and leverage commercial financing for energy efficiency projects and help commercial banks develop streamlined procedures for project appraisal and loan disbursement. The fund provides capital to Thai banks to fund energy efficiency projects, and the banks provide low-interest loans to energy efficiency projects in industries and buildings. It represents a working partnership between the RTG and 11 commercial banks.

Phase I of the TEERF was launched in 2003 as a three-year program and has been renewed for two additional three-year terms. By April 2010, the TEERF had financed 335 energy efficiency projects and 112 renewable energy projects. The total investment in these projects was US$453 million, and the estimated annual energy cost savings were US$154 million, providing an average payback of about three years.

8.3.1.3 Indian KfW SME Credit Line

The Kreditanstalt für Wiederaufbau Bankengruppe (KfW) of Germany has provided a dedicated credit line of EUR 50 million to the SIDBI to finance energy efficiency projects in micro-, small and medium enterprises (MSMEs) in India (KfW and SIDBI 2010). The credit line provides SIDBI the capacity to encourage micro-, small, and medium enterprises (MSMEs) to undertake energy saving investments in plant and machinery and production processes. KfW has also provided a technical assistance component to support SIDBI in identifying key target MSME clusters, setting up the credit lines, providing technical support, and conducting awareness campaigns in MSME clusters throughout India. The program's overall objective is to save energy and reduce greenhouse gas emissions. Specifically, the program sought to (1) increase investments of MSME in energy efficiency; (2) increase the contribution of MSME to ecologically sustainable economic development; and (3) broaden the financial instruments of SIDBI.

A part of the credit line funds was channeled by SIDBI through private and public sector "partner lending institutions." Another part is disbursed by SIDBI directly to MSME clients. A key requirement of this dedicated line of credit is that each project should achieve a minimum level of energy savings and GHG emission reductions. KfW and SIDBI have agreed that at least 25 tonnes of GHG emission reductions should be reached for every US$22500 invested. As part of its drive to be a market leader in energy efficiency financing in India, SIDBI is increasingly institutionalizing its knowledge in energy efficiency lending, e.g., by setting up an "energy efficiency cell" within the organization. Table 8.2 presents the three examples of dedicated credit lines illustrating the range of possible features and commitment of funding.

Table 8.2 Three dedicated credit lines for energy efficiency feature

Feature	China CHEEF I	Thailand TEERF	India SME credit line
Public partner	World Bank	Government of Thailand ENCON Fund	KfW/SIDBI
Local financial Institution (LFI)	Exim Bank and Huaxia Bank	11 commercial banks in Thailand	SIDBI, private and public partner lending institutions
Amount of credit line	US$100 million to each bank	US$192 million	€ 50 million
Co-funding from banks	Minimum US $100 million each	Varies by bank	None required
Sectors targeted	Medium and large industries and ESCOs	Industrial and commercial energy users and ESCOs	MSMEs
Percentage of debt financing	70 %	Maximum 70 %	70 %
Maximum loan size	US$17.5 million	US$1.4 million	Borrowers must be defined as SME according to Indian regulation, no additional limit on loan size

8.3.2 Risk-Sharing Facilities

Examples of risk-sharing facilities include the IFC/GEF Commercializing Energy Efficiency Finance (CEEF), the IFC/GEF China Utility Energy Efficiency (CHUEE) Program, and the World Bank China Energy Conservation II Program.

8.3.2.1 IFC/GEF Commercializing Energy Efficiency Finance (CEEF)

One example of successful implementation of a risk-sharing facility was CEEF program offered as a joint program of the IFC and the GEF, with IFC acting as the Executing Agent for the GEF. The program covered six countries in Eastern and Central Europe (Hungary, Czech Republic, Slovak Republic, Latvia, Lithuania, and Estonia). The CEEF program was designed to meet the GEF objectives to promote and enhance commercial financing of energy efficiency projects, thereby leading to reduction of GHG emissions and creation of a sustainable market in the CEEF countries for energy efficiency project development and financing.

Two key tools were introduced by CEEF to achieve these objectives. The first was risk-sharing and risk management through partial credit guarantees provided to LFIs for loans to energy efficiency projects. The second was technical assistance for capacity building within LFIs, ESCOs, project developers, and project hosts. The CEEF provided partial guarantees to share the credit risk of energy efficiency finance transactions, which the partner LFIs would fund with their own resources. The transactions eligible for the program included capital investments aimed at improving energy efficiency in buildings, industrial processes, and other energy end-use applications.

The IFC used a 50 % without partiality risk-sharing structure for CEEF. The GEF committed US$17.25 million to the program, of which US$15 million was for the guarantee facility, and the remaining US$2.25 million was used for program operating costs and for technical assistance.

The technical assistance of the program aimed to help identify and prepare projects for investment and build energy efficiency and LFI capacities in each country. The program provided assistance to participating LFIs to market their energy efficiency finance services, prepare projects for investment, develop new energy efficiency finance products, and build their capacities to originate energy efficiency project financings. It also included assistance to energy efficiency and ESCO businesses for building their corporate capacities and developing energy efficiency projects.

Under the CEEF program, 14 participating LFIs financed 829 projects. The total amount of the guarantees was US$49.5 million. These projects represent a total investment of approximately US$208 million.

8.3.2.2 IFC/GEF China Utility Energy Efficiency Program

The IFC, in cooperation with the GEF, initiated the China Utility-Based Energy Efficiency Finance Program (CHUEE) in June 2006. To implement energy efficiency projects in China, CHUEE-supported services such as marketing, project development, and equipment financing for energy users in the commercial, industrial, institutional, and multi-family residential sectors. The program brought together financial institutions, utility companies, and suppliers of energy-efficient equipment to create a new financing model for the promotion of energy efficiency. CHUEE program cooperated with Chinese commercial banks and offered them a facility whereby IFC shared part of the loss for all loans within the energy savings and the GHG emission reduction portfolio. The program also provided technical advisory services related to marketing, engineering, project development, and equipment financing services to banks, projects developers, and suppliers of energy efficiency and renewable energy products and services.

In the CHUEE scheme, the IFC provided a "Loss-Sharing Agreement" with partner banks. Losses were defined on a portfolio basis and were defined as 10 % of the total original principal amount of the loan portfolio. In the first-generation loss-sharing agreement, IFC shared 75 % of the "first losses." Second losses were defined as all losses after the first losses; these were shared 40/60 between IFC and its partner banks. IFC also provided technical assistance to the banks.

Although the initial IFC model was to work with a utility, the IFC found that a strategic mismatch existed between the utility and the financing partners (World Bank 2010). The gas utility's customers were primarily small customers, and the participating banks preferred to work with large customers only. As a result, the IFC worked directly with the banks, without any utility involvement. As of September 2012, the CHUEE program's participating banks have provided loans worth over US$800 million, financing more than 170 energy efficiency/renewable energy projects. These investments are estimated to reduce over 18 million tonnes of carbon dioxide emissions every year—the equivalent to the total annual emissions of Mongolia (IFC 2014).

8.3.2.3 World Bank China Energy Conservation II Program

With funding from the GEF, the World Bank has supported the development of ESCOs in China, as well as related contracting and financial mechanisms under the China Energy Conservation Project in two phases. In Phase II of this project, the World Bank established a goal to mobilize local banks to provide ESCOs with debt financing for energy efficiency projects. The project used a loan guarantee mechanism, with China National Investment and Guarantee Company Ltd., a state-owned national guarantee company, acting as guarantor (World Bank 2002). World Bank/GEF funds were provided through the Ministry of Finance to serve as guarantee reserves and were made available on a formula basis for the I&G to pay guarantee claims. With these resources, the I&G provided 90 % loan guarantees to commercial banks that make loans to ESCOs for qualified energy efficiency projects. In addition, the World Bank-supported establishment of the Energy Management Company Association of China, as an institution to provide support to ESCOs, and as a way to provide technical assistance to newcomers and to represent the emerging industry to the Chinese government and other parties.

The ESCO Loan Guarantee Program helped create a bridge into the world of formal energy efficiency financing for many ESCOs. With the backing of US$16.5 million placed in a special guarantee reserve fund held by the Ministry of Finance, the I&G issued loan guarantees totaling approximately US$52 million from 2004 through April 2008, which provided support for energy performance contracting project investments totaling about US$90 million. Nearly 40 Chinese ESCOs have received loan guarantees for one or more of their projects. Twelve banks participated in this program.

The program had several key features. First, GEF funds, through the Ministry of Finance, were used for program operations, technical assistance, and guarantee reserves. Second, the World Bank and the Ministry of Finance of China entered into a guarantee program operations agreement with the I&G. Third, the I&G marketed, appraised, and originated guarantees with ESCOs and banks. As a result, the guarantee was a three-party agreement that guaranteed 90 % of the bank's principal. Guarantee fees were paid by the ESCO as borrower. Table 8.3 compares the three programs with eight key parameters.

Table 8.3 A comparison of the three risk-sharing programs

Program	GEEF	CHUEE	China ECII
Public partner	IFC/GEF	IFC/GEF	World Bank/GEF
Private partners (LFIs)	14 participating banks	Industrial Bank and Bank of Beijing	China National Investment and Guarantee Company (I&G)
Risk sharing (public/private)	50/50 without partiality	First 10 %: 75/25 After 10 %: 40/60	90 %
First-loss reserve	GEF: US$15 million	None	GEF: US$22 million
Target markets	Commercial/ industrial firms and ESCOs	Large industries	ESCOs
Total project investments	US$208 million	US$512 million	N/A
Total value of guarantees provided	US$49.5 million	US$197 million	N/A
Estimated CO_2 reduction	145,700 tonnes per annum	14,000,000 tonnes per annum	N/A

Source Developed by authors

8.3.3 *Energy Saving Performance Contracts*

8.3.3.1 World Bank/GEF Financed China Energy Conservation Project

China's ESCO industry was launched as part of a deliberate plan by the Chinese government, with support from the World Bank, the GEF and several other international donors. In the mid-1990s, China was in transition from a planned economy to a market-oriented economy. The government was enthusiastic about the potential for energy performance contracting by ESCOs as a new, market-based mechanism which might operate in the newly emerging market economy. In 1995–1996, the government was seeking technical and financial assistance from the World Bank and the GEF to introduce and develop energy performance contracting for the first time in China. In March 1998, the World Bank started implementing the China Energy Conservation Project, providing US$15 million GEF grants and US$63 million International Bank for Reconstruction and Development loans through the Chinese government to three new pilot Chinese ESCOs to implement the pilot energy saving performance contracts program.

The three Chinese ESCOs were established in Liaoning province, Shandong province, and the Beijing municipal government. The ESCOs were called Energy Management Company (EMC). They were new shareholding companies at that time and registered under China's new Company Law, which had become effective in 1994.

The program was successful in terms of public and private partnership for ESCO development. With the GEF grant, international advisors were hired and worked at each of the three Chinese ESCO companies for several months to develop initial project pipelines. The GEF grant also supported for immediate implementation of small, trial investment projects. In each of the provinces and city, provincial stakeholders, including provincial government investment companies, electric power companies, and other enterprises, mobilized at least US$2.4 million as equity investment from different companies. With this program, the specialized energy performance contracting business model was formally introduced to China.

The Energy Conservation Project had a major advantage when compared with some other similar international projects aiming at supporting ESCOs. It provided the ESCOs with a dedicated and large line of credit from the beginning of project financing, which allowed the ESCOs to focus almost exclusively on technical not financial challenges.

Technically, all three companies started with a mix of simple commercial lighting projects, industrial boiler and furnace renovations, industrial variable speed drive motor applications, and many simple industrial equipment retrofits. All developed projects were implemented with the "shared savings" energy performance contracting model.

After a couple of years, these three companies began to develop their own personality and market approaches. Liaoning Energy Management Company focused strongly on industrial boilers and kilns and began to expand its roster of technical staff to develop increasingly diverse and sophisticated industrial projects. The Beijing EMC focused less on industrial projects but more on commercial and residential building energy savings and coal substitution projects. Shandong EMC maintained its strong focus on industry and gradually increased the size and sophistication of its projects, with an emphasis on developing long-term relationships with key industrial clients.

As the three pilot ESCOs began to ramp up the new business in 1998–2000, they encountered numerous problems. Some stemmed from lack of familiarity with the idea in the marketplace. Others stemmed from difficulties in the financial and legal regulatory systems to categorize the business, which combines service aspects, equipment procurement and sale, and project financing. Some financial auditors had difficulty with the notion that the companies' assets were located on the premises of other enterprises. Arguments began as to how accounting should be done and how the companies should be taxed. At one point, each of the three had reported their accounts using a different business classification: one as a service company, one as an equipment vendor, and another as a financing entity. Some local authorities began to declare that the energy performance contracting business was illegal. As these problems surfaced, senior authorities in the Chinese government worked with local officials to research the issues and find solutions. Without this strong and steady national government support, the Chinese nascent ESCO industry would have been failed.

The three ESCOs showed strong revenue growth from the beginning. After a slow start, profits were declared by each during the last four years of the project, producing strong growth in net worth during 2002–2006. Capital investments rose to over US$20 million per year during 2002–2004, and over US$30 million per year during 2005–2006. Total energy performance contracting investments reached US$181 million by June 2006, when this component of investment mobilization of the China Energy Conservation Project closed. This project had laid a foundation for a number of forthcoming energy efficiency projects in China, including CHUEE.

8.3.4 Leasing

8.3.4.1 Turkey Commercializing Sustainable Energy Finance Program

Turkey's industrial energy consumption is more than three times above the OECD average due to a reliance on outdated equipment. To improving energy efficiency in the country, the IFC and the Climate Investment Fund (CIF) jointly developed the Turkey Commercializing Sustainable Energy Finance Program.

The Program comprises an investment and advisory services (formerly known as technical assistance) component to support the scale up of energy efficiency projects in Turkey's SME, commercial, residential, and municipal sectors. The investment component aims to transform Turkey's financial sector toward low-carbon, climate-sensitive behavior and support the economic development and social well-being of people. The Program encouraged LFIs to develop lending programs for small-sized carbon-mitigating investments such as energy efficiency projects and small-scale renewable energy investments in the sectors noted above. Leasing companies finance a variety of technologies including cogeneration units, boilers, compressors, chillers, control systems, energy efficiency motors, and varied-speed drives and other energy-efficient technologies. The Program's advisory services component supported the investment component by addressing many of the knowledge and capacity barriers outlined above.

In 2010, the CIF initially put US$22 million as seeds capital in Yapi Kredi Leasing (YKL), Turkey's leading leasing company. Supported by the CTF, IFC provided YKL with a US$50 million line of credit, when its SME energy efficiency finance portfolio was just US$18.8 million. Today that same portfolio stands at US $200 million. The YKL used the capital to leverage co-financing from the SME, commercial, residential, and municipal sectors. In 2013, YKL's SME energy efficiency finance portfolio grew to US$200 million (Jain 2014).

YKL is a subsidiary of parent Yapi Kredi Bank, winner of Turkey's Bank of the Year award in 2011 from the Banker, a Financial Times publication. In 2008, YKL became the first local Turkish financial institution to partner with the IFC in this regard. Looking for a specialized market niche, it wanted to develop its energy efficiency equipment business as well.

8.4 Summary

Dedicated credit lines, risk-sharing facilities, energy saving performance contracts, and leasing for energy efficiency financing can serve as effective approaches to realizing energy efficiency investments. Practice has shown that these means have been successfully applied in many countries, including the USA, Japan, China, India, and many countries in the EU.

The four approaches discussed in this chapter are applicable in different market environments and represent different degrees of public and private financing approaches. The application of financial approaches and structures for energy efficiency financing depends on a number of characteristics including the country context, the legislative and regulatory framework, the existing energy services delivery infrastructure, and the maturity of the commercial and financial market. Some approaches and structures are particularly successful in some countries but may not so in others. For example, energy savings performance contracting was very successful in the USA and China, but not in Eastern Europe.

These four approaches may not provide solutions to every problem or barrier related to scaling up of energy efficiency project implementation, nor are they applicable under all circumstances. Some approaches may be complex and difficult to standardize, structure, and manage. When designed and implemented appropriately, however, these financial approaches can be a powerful tool to overcome many energy efficiency project implementation barriers including financing barriers.

There is a need to further enhance these financial approaches. For example, more efforts are needed to develop a third-party-involved simple, efficient, and transparent monitoring and verification (M&V) mechanism for the four financial approaches. Further expansion of opportunities and mechanisms for greater formal financing of ESCO projects highly depend on the third party that is recognized by the government. So far, little progress has been made in this area in recent years, although some national governments have initiated the development of such M&V entities.

ESCOs are playing a very important role in energy efficiency project financing. In the next chapter, the development of ESCOs is discussed in more detail.

References

Hansen S, Langlois P, Bertoldi P (2009) ESCOs around the world: lessons learned in 49 countries. The Fairmount Press, Lilburn

IEA (2010) Energy efficiency governance. IEA, Handbook, Paris

IFC (2014) China utility-based energy efficiency finance program (CHUEE). http://www.ifc.org/wps/wcm/connect/regprojects_ext_content/ifc_external_corporate_site/home_chuee/about+us/about. Cited on 21 Jan 2014

IIP—Institute of Industrial Productivity (2014) China energy efficiency financing. http://www.iipnetwork.org/IIP-FinanceFactsheet-1-CHEEF.pdf. Cited on 27 Apr 2014

Investopedia (2014) Definition of project finance. http://www.investopedia.com/terms/p/projectfinance.asp. Cited on 20 Jan 2014

Jain A (2014) Win-win for Turkish leasing company: investing in energy efficiency opens new markets and fights climate change, IFC. https://www.climateinvestmentfunds.org/cif/node/8585. Cited on 21 Jan 2014

KfW and SIDBI (2010) Operating guidelines for KfW energy efficiency line of credit—assistance for energy efficiency projects

Mostert W (2010) Publicly-backed guarantees as policy instruments to promote clean energy, UNEP—sustainable energy finance alliance

Motiva (2005) International review of ESCO activities. Helsinki, July

Singh J, Limaye DR, Henderson B, Shi X (2010) Public procurement of energy efficiency services. The World Bank, Washington

SRC Global Inc. (2005) A strategic framework for implementation of energy efficiency projects for Indian water utilities, prepared for The World Bank, Public-Private Infrastructure Advisory Facility, May 2005

The World Bank (2010) Assessing the impact of the china utility energy efficiency finance program. Independent Evaluation Group, Washington

World Bank (2002) Project appraisal document, on a proposed GEF grant of SDR19.7 million (US $26 million equivalent) to the People's Republic of China for the second energy conservation project, September

World Bank (2008) Project appraisal document on a proposed loan in the amount of US$200 million and a proposed grant from the global environment facility trust fund in the amount of US$13.5 million to the People's Republic of China in support of the energy efficiency financing project, April 21

Chapter 9
Energy Service Company Development

Abstract ESCOs and the energy market for ESCO financing have been developing since 1976 when oil prices increased dramatically. ESCOs' services cover projects in many energy areas, including energy extraction, power generation, energy conversion, transportation, power transmission, energy consumption, project financing, energy project audits, monitoring, and energy savings verification. In developing countries, there are many barriers in the energy market that are preventing ESCOs from developing. These barriers include lack of appropriate policy, financial mechanisms, and local capacities for ESCO development and management. Over the past 20 years, the GEF financed 39 ESCO projects in 25 countries and regions to remove these barriers. The results of these projects show that some countries are very successful in ESCO development, but others are not. Different models of ESCOs in different financial markets in various countries are analyzed; case studies are undertaken for China, India, Ukraine, and Brazil. This chapter concludes that while developing financial markets for ESCOs, countries need to consider the following: (1) initiating national government policy to stop energy subsidies and to reform energy pricing, (2) establishing a real, market-based financial mechanism for ESCOs, (3) involving the private sector in project co-financing, (4) creating incentives to ESCOs in the market by investing part of government revenue from energy tax, and (5) incentivizing ESCOs by government corporate tax exemption.

9.1 Introduction

The rise of ESCOs can be attributed to the energy crisis of the late 1970s, as oil importing countries developed new approaches to mitigate the impacts of increasing energy costs. One of the earliest approaches was used by Time Energy, a company in Texas, USA, which introduced a device to automate the switching on and off lights and other equipment to regulate energy use. Using this approach, the company was able to achieve a higher return and sales due to the large energy savings.

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_9

The approach and result were the basis for the ESCO model in the USA (Bullock and Caraghaiur 2001).

The ESCO industry grew slowly through the 1970s and 1980s. As more entrepreneurs saw this market grow, more companies were created. The first wave of ESCOs was mainly comprised of small divisions of larger energy companies or small, upstart, and independent companies. However, after the energy crisis ended, the companies had little leverage over potential clients to perform energy saving projects, given the lower cost of energy. This prevented the continuation of the growth experienced in the late 1970s.

Utilities and consolidated energy companies became major players in the 1990s. With the rising cost of power supply and the availability of efficient technologies in lighting, heating, ventilation, air conditioning, and energy management systems in buildings; ESCO projects became more commonplace. The term ESCO had also become more widely known among potential clients looking to upgrade their building systems that were outdated and needed to be replaced. Over the past four decades, the USA has become a leader in ESCO development, since the US federal government mandated utilities to conserve energy. ESCOs were established to provide services such as energy audits and energy-efficient equipment retrofitting. Following the shared savings model, utilities also paid fees to ESCOs for their services on the basis of negotiated contracts. Afterward, between 1986 and 2000, the US ESCO industry grew dramatically due to the nationwide DSM campaign. The US utility regulators made energy conservation part of long-term utility resource plans. Power utilities were required to undertake feasibility studies for both physical power plants and energy efficiency power plants,[1] while planning to invest in new power generation capacity to meet their increasing demand. For most power expansion plans in US utilities at the time, energy efficiency power plants were cheaper than new power generation plants. Between 1995 and 2000, the US federal government implemented ESPCs and state governments authorized ESPCs, which facilitated the development of ESCO business in the USA. The guaranteed savings model was developed and widely used in the USA, and the utilities paid 80–100 % of energy efficiency project costs in this period. However, between 2000 and 2004, ESCOs in the USA were scaling back due to a number of issues, including power utilities' unbundling and expiration of the federal government's ESPC legislation. Power generation companies had little interest in DSM, and the federal government downgraded energy efficiency as a moral virtue, not an energy resource. After a few years of setback, triggered by increasing energy prices and climate change, using the guaranteed savings model in the USA, the ESCO industry has boomed again since 2009 with the President Obama administration. Besides focusing on public buildings and utilities, ESCOs expanded their services into distributed generation, renewable power, building/owning and operating generation facilities, street

[1] Energy efficiency power plants are not tangible power plants. They are energy-efficient technologies which save energy at the end-use. Their function to the power system is similar to that of power generation plants.

lighting, and energy and water resource management-related business. By 2011, the USA had developed an ESCO market with transactions of over US$5 billion per year (Weiss 2013).

ESCOs are usually private, commercial, or nonprofit firms providing energy services to promote energy efficiency. Typical ESCO services include developing, designing, de-risking, arranging finances for energy efficiency projects, installing and maintaining energy efficiency equipment involved, and measuring and verifying energy savings. Energy efficiency projects can cover all energy areas, from energy extraction, to conversion, transportation, transmission, and consumption. There are two important features of ESCOs that differentiate them from traditional energy consulting firms or energy suppliers. First, ESCOs finance, or arrange financing, for the operations of energy efficiency projects. Second, ESCO business is conducted on a performance-based contractual agreement, which means that the ESCO's payment is directly linked to energy savings achieved either in physical or monetary terms. There are three main ESCO financing models: (1) shared savings, (2) guaranteed savings, and (3) outsourcing of energy management. In the first model, an ESCO will finance the projects and share guaranteed cost savings with a customer at a predetermined percentage for a fixed number of years. Benefits from energy savings from projects will be transferred to the customer after the contract ends. In this model, the ESCO assumes both the performance and the credit risks.

In the second model, clients raise funding from their own capital resources or from commercial banks. An ESCO installs the equipment for the project and guarantees a certain level of cost savings or energy savings to the customer. The customer pays the ESCO, according to their contract, after the project installation is finished. The ESCO will have to refund the customer if scheduled savings are not achieved during the project implementation. In this model, the ESCO assumes the performance risk and the customer takes credit risk. This model is based on customer financing or third party financing. The third party lender will finance the project, and the facility owner shares the risk by having recourse to the ESCO's guarantee. This model shares the risk between the parties involved. Interest rates in the second model are usually much lower than the first model; therefore, more energy efficiency investment is possible, and it is the most popular model used for financing energy efficiency projects.

In the third model, customers or ESCOs rent equipment or energy systems from leasing firms, and customers entrust and pay ESCOs for the management of their energy systems. ESCOs may own part of the savings according to their contracts and customers gain benefits by reducing energy bills. The third model can be very beneficial for both ESCOs and customers because the debt service is treated as an operational expense, not a capital obligation in the balance sheets of the ESCO or the customer. The above ESCO financing models have been developed and used over time, along with the development of ESCOs worldwide.

The success of the ESCO industry in the USA sets an example for the rest of the world. The objectives of this chapter are to find out barriers that cause slow growing of ESCO industries and to recommend policy instruments to unlock these barriers. Four case studies are presented to show GEF-financed ESCO industry development in China, India, Ukraine, and Brazil. A comparison analysis among these four countries follows. This chapter concludes that government policies and incentives to develop a market-based financial mechanism are most important for the success of the ESCO industry in developing countries and countries with economies in transition. Several recommendations on further development and selection of potentially successful ESCO projects are also presented.

9.2 Case Studies of GEF-Supported ESCO Projects

The GEF unites 183 countries in partnership through the use of international institutions, civil society organizations, and the private sector, to address global environmental issues, including climate change. Since 1991, the GEF has performed a catalytic, innovative, and cost-effective role, led in financing new and emerging low carbon technologies, and pioneered market-based approaches and innovative instruments. The GEF has provided over US$4 billion for more than 600 climate change projects and programs in 157 countries, leveraged more than US$27 billion in co-financing, avoided 2.6 billion tonnes of CO_2 through project development and finance, and catalyzed the reduction of 6.8 billion tonnes of CO_2 through market transformation.

The GEF has been a global catalyst for the development of ESCOs. As at May 2014, it has financed 39 ESCO projects in 25 countries and regions (Table 9.1). The World Bank (WB), the UNDP, the Inter-American Development Bank (IADB), the ADB, the African Development Bank (AfDB), the United Nations Environment Programme (UNEP), the European Bank for Reconstruction and Development (EBRD), and United Nations Industrial Development Organization (UNIDO) have provided technical support to these countries in ESCO industry development. Some countries received more GEF funding and technical support than others. For example, Ukraine used approximately US$16 million GEF funding in four ESCO projects, while Cote d'Ivoire utilized US$695,000 in one project. The total GEF resources in ESCO project financing amounted to approximately US$213 million and mobilized more than US$2.3 billion co-financing from governments, private sector investments, supporting agencies, and other project stakeholders. Each GEF dollar has mobilized 11 dollars of co-financing in the GEF ESCO projects. These 39 GEF-funded ESCO projects will likely mitigate 324 million tonnes of CO_2.

As at May 2014, most of the GEF-financed ESCO projects were completed. Practice showed that some of the projects were very successful and some were not. It is necessary to conduct an analysis and find the reasons behind this. Since China, India, Ukraine, and Brazil use the greatest amounts GEF funding to finance ESCO projects, they have been selected for analysis.

Table 9.1 GEF-supported global ESCO projects

Country name	Number of projects	Supporting agencies	GEF grant (US$)	Co-financing (US$)	Ratio of co-financing funds to GEF funds	Targeted GHG reductions (million tonnes)
China	3	ADB, IFC, WB	32,136,363	471,500,000	14.7	8
India	3	UNDP and WB	27,006,849	658,800,000	24.4	99
Ukraine	4	UNDP and UNIDO	15,954,000	38,306,000	2.4	85
Regional (Egypt, Jordan, Morocco, Tunisia)	1	EBRD	15,000,000	141,250,000	9.4	14
Romania	2	EBRD and WB	14,570,000	121,250,000	8.3	8
Brazil	1	UNDP and IADB	13,500,000	64,825,000	4.8	12
Croatia	2	UNDP and WB	11,390,000	32,060,000	2.8	4
Regional (Czech Republic, Slovak Republic, Estonia, Latvia, Lithuania)	1	WB and IFC	11,250,000	20,850,000	1.9	7
Poland	1	WB	11,000,000	88,000,000	8.0	1
Tunisia	1	WB	8,500,000	23,300,000	2.7	1
Morocco	3	AfDB, UNDP, WB	6,119,726	44,105,000	7.2	1
Indonesia	1	WB	5,480,000	244,000,000	44.5	5
Iran	1	UNIDO	5,450,000	15,150,000	2.8	29
Chile	2	IADB	5,001,000	28,696,000	5.7	2
Vietnam	2	UNDP and UNIDO	4,969,000	25,850,000	5.2	5
Regional (Antigua and Barbuda, Belize, Grenada, St. Lucia, Trinidad and Tobago)	1	UNEP	4,859,000	6,355,000	1.3	16
Colombia	2	UNDP and IADB	3,975,000	20,645,000	5.2	5
Maldives	1	UNEP	3,885,000	21,250,000	5.5	0
Turkey	1	WB	3,640,000	252,500,000	69.4	10
Kenya	1	UNDP	3,153,000	5,090,000	1.6	4
Regional (Czech Republic, Slovak Republic)	1	UNEP	2,020,000	7,400,000	3.7	5
Armenia	1	UNDP	1,600,000	8,600,000	5.4	1
Moldova	1	UNDP	1,300,000	7,300,000	5.6	0
Fiji	1	UNDP	740,000	670,000	0.9	0
Cote d'Ivoire	1	WB	695,000	265,000	0.4	0
Total	39		213,193,938	2,348,017,000	11.0	324

9.2.1 China

China started its ESCO industry development in the late 1990s. In 1997, when market-based institutions, such as ESCOs, developed rapidly in the USA and other countries to pursue contract energy management ventures, China did not have such institutions and contracts. There were not any international ESCOs active in China either. Reasons include a lack of familiarity with, and experience in, the ESCO concept, and the difficulties and risks of establishing and enforcing energy management contracts. To overcome these barriers, the GEF, the WB, the Asian Development Bank, and the IFC initiated and financed three ESCO projects in China. The objectives of the projects were to achieve large and sustainable increases in energy efficiency, reduce CO_2 emissions and other pollutants, and introduce, demonstrate, and disseminate new project financing concepts and market-based institutions to promote and implement energy efficiency measures in China. One of the important outputs of the projects was the development of ESCO business in Chinese provinces and cities. The total GEF grants amounted to US$32 million, and the total budgeted project costs were approximately US$500 million. Fully endorsed and supported by the Chinese government, the project successfully introduced and promoted three ESCOs and energy savings-based business models.

After the initial success of ESCO development, the GEF continued supporting the Chinese ESCOs with emphasis on policy development, government incentive schemes, capacity building, and market-based financial mechanisms in various provinces and cities in China. The GEF and the Chinese government have instituted a number of policy incentives to catalyze ESCOs in China. These included as follows: (1) exempting from corporate income tax for the first three years, (2) reducing 50 % corporate income tax for the second three years, (3) exempting ESCOs from value-added tax, (4) allowing state-owned enterprises to pay ESCO services out of their energy budgets, and (5) allowing ESCO fees to be paid pre-tax (Zhao 2013).

Besides policy incentives, the GEF has also developed a sustainable market-based financial mechanism in China to catalyze ESCOs. Since 2006, in partnership with the IFC, the Chinese Ministry of Finance, and the governments of Finland and Norway, the GEF financed the CHUEE, which enabled local commercial banks, ESCOs, the private sector (energy end users and companies), and government agencies to collaborate in creating a sustainable energy financing market. In this project, the GEF provided a US$16.9 million grant, and the IFC put up a US$200 million loan for energy efficiency marketing, development, and financing services. The GEF grant was used to set up a loan guaranteeing fund. With loan guarantee, commercial banks are able to lend to ESCOs or private firms with reduced interest rates for the development and investment in energy efficiency and renewable energy projects. The IFC helped local banks build their pipelines, portfolios, experience, and expertise in the sustainable energy finance market and assisted in assessing the risks and opportunities of the renewable energy and energy efficiency projects. By 2013, the project leveraged over US$800 million from local banks and the private sector for more than 170 energy efficiency and renewable projects, which were expected to mitigate more than 19 million tonnes of CO_2 per year (IFC 2013).

Compared with the history of ESCO development in the USA, China's ESCOs have the following features:

1. Small-scale business operation. As at November 2013, there were over 1,850 registered ESCOs in China. Most of these ESCOs have a short history of business operations. They are usually small and do not have significant cash assets. Each of these ESCOs focuses on a single energy efficiency area and uses a different measure to improve energy efficiency. They are looking for projects with very short payback periods, such as one year or two years. Generally speaking, they use their own contracts instead of standard contracts. With short-term financing for projects, they prefer to hire contracted staff to do the work and perform one-time verification for the completed projects. As such, these small ESCOs are more risky for commercial banks to finance.
2. Shortage of ESCO expertise within commercial banks. The Chinese financial mechanism for ESCOs has been developing since 2006. This mechanism has not matured yet. Not many commercial banks have experience in financing ESCO energy efficiency projects. They need a guarantee from a third party while financing ESCO projects.
3. Focusing on industry. The Chinese ESCOs started their business from the industrial sector, while the USA started from public, commercial, and residential buildings. Financing an energy efficiency project in the industrial sector tends to be more risky than one in the public sector, where there is a guaranteed annual budget to pay energy bills.
4. Focusing on technology deployment. The Chinese ESCOs usually use market-approved energy-efficient technologies and deploy them in the market; they do not develop or undertake research of energy-efficient technologies.
5. Shared energy savings model and equipment leasing model. The Chinese ESCOs use shared savings model in business, namely the ESCOs got loans from commercial banks to finance the projects and shared savings with customers. Recently, an equipment leasing model has been developed and deployed in China. More and more ESCOs install rental equipment and machines for customers without paying back the capital used to finance them.

The China's ESCO industry is sustainably growing up. By the end of 2012, the number of registered ESCOs in China amounted to 1,850, and the ESCO industry created 430,000 jobs for the Chinese market. Annual turnover of ESCO industry reached US$27 billion (RMB165.3 billion), more than four times the annual turnover of the US market (Zhao 2013). The ESCO industry helped to save 17.7 million tonnes of coal equivalent, the equivalent of reducing 49 million tonnes of CO_2 emissions per year.[2] This is approximately the same amount that is emitted from 9,000,000 cars in the USA per year.

Large ESCOs are emerging in China. Realizing the importance of energy efficiency, some large, public-owned Chinese firms, such as Shenhua Group, China Southern Power Grid, China State Power Grid, China Guangdong Nuclear Power Investment, Sinopec, Anshan Iron and Steel, Sinochem, Huadian, and Datang, established subcompanies to finance and implement energy efficiency projects from within. These subcompanies, once mature, will likely turn into large commercial ESCOs in China.

The GEF funding that has been invested in the GEF/IFC project will continue supporting the Chinese ESCOs. As at November 2013, shared savings was the dominant ESCO model, which needs the continued support of loan guarantees to reduce the loan interest. The GEF's grant will therefore continue functioning as a loan guaranteeing fund in China to reduce loan interest for the Chinese ESCOs.

Looking ahead, China's ESCO development may follow the footstep of the USA. This includes the following:

1. ESCOs will focus on not only industry but also other sectors, such as government buildings, schools, and commercial buildings;
2. technology research and development of energy efficiency may also become part of ESCO's business, which will likely happen when the Chinese ESCO companies become large and international;
3. ESCOs use third party direct financing (or use guaranteed savings model as in the USA), which will help the Chinese ESCOs work on large and multi-area energy efficiency and renewable energy projects;
4. if the Chinese government allows private banks to operate in China, the Chinese ESCO industry will likely be further prospering, since the private banks usually have short cycle of evaluation and approval of loans;
5. with the development of large ESCOs for large energy efficiency and renewable energy projects, long-term financing for projects will become mainstream in the ESCO market;
6. ongoing savings verification schemes will likely be developed and implemented to meet requirements of serving large and long-term financing projects; and
7. integrated energy efficiency improvement and renewable energy generation measures and standard contracts for ESCO projects will also be developed with the growing ESCOs.

[2] Calculated by the author on the basis of the IPCC default carbon emission factors from the 1996 IPCC Guidelines: 25.8–29.1 tC/TJ for primary coal products.

9.2.2 India

Similar to China, India started its ESCO industry in the 1990s. In 1998, the GEF, along with the WB, financed the first GEF ESCO project in India on Energy Efficiency Project and Second Renewable Energy. The project helped overcome the barriers to private investment in energy efficiency by catalyzing, supporting, and funding ESCOs and directly financing, end user, energy efficiency investments. The GEF provided US$5 million as grant and the WB provided a US$32 million loan for the project. The GEF grant the following: (1) developed capacity for Indian Renewable Energy Development Agency Limited to identify, appraise, and finance ESCOs and end user defined energy efficiency investments; (2) tested the performance of different energy efficiency projects and ESCO financing modalities; and (3) disseminated information on the benefits and risks of energy efficiency investments. This investment aimed at avoiding over 9.43 million tonnes of CO_2 emissions (World Bank 2008). After the first GEF/World Bank project, the GEF continued financing other two ESCO projects in India. The total GEF funding in ESCO project financing in India reached US$27 million, and this funding mobilized at total of US$659 million co-financing. These projects aimed at reducing approximately 100 million tonnes of CO_2 in their project lifeline.

Since 1998, with increasing energy costs and the government policy prompting energy efficiency in industrial enterprises, ESCOs in India have been developing quickly. From 2003 to 2007, the ESCO industry revenues grew with an annual rate of 95.6 % (Delio et al. 2010). This growth is expected to continue due to immense untapped investment potential and several new entrants making their way into the industry. By 2008, when the GEF project was closed, there were more than 25 ESCOs operating in India. The estimated investment potential in energy efficiency the country by ESCOs was US$9.8 billion.

Compared with the ESCO financing market in China, the financial market in India does not provide equal opportunities for access of ESCOs. India's ESCO financing is generally limited to direct investment by the large ESCOs, each of which has annual revenues of US$200,000 or above. Most of the ESCOs in India are affiliated with, or owned by, equipment or control manufacturers. These companies do not report problems with funding projects, although some of their clients may still have some difficulties in providing the financing. Smaller ESCOs, however, have difficulties in accessing funds from banks, because they lack the collateral to meet bank requirements. Unlike the financing model in China, commercial banks in India are not widely engaged in financing energy efficiency projects. In order for ESCOs to obtain market rate financing for energy efficiency projects, banks must understand the energy and cost savings that ESCOs can guarantee. Lack of ESCO knowledge and confidence in Indian commercial banks are key barriers to ESCO development in India.

Going forward, the ESCO industry will likely develop at a large scale once the financial market barrier is overcome. Like China, India has great potential for energy efficiency improvement. Power and heat cogeneration, industrial waste heat utilization, and energy efficiency improvement in buildings and in the industrial sector offer excellent opportunities for ESCOs to invest and make profits in India.

9.2.3 Ukraine

Ukraine's energy market provided a great opportunity for ESCO development in the country. In the late 1990s, Ukraine was one of the least energy-efficient countries in the world. Per capita emissions of CO_2 were 4.75 tonnes per year, which was one of the highest in the world. Heat supply in the buildings sector accounted for approximately 25 % of all fuel consumed in Ukraine. There was a huge potential for energy efficiency improvement in this sector. In the meantime, Ukraine imported energy from Russia which creates an energy security issue to the country.

In 1998, the GEF financed a project in Ukraine to remove barriers to greenhouse gas emissions mitigation through energy efficiency in the district heating system, which would improve energy efficiency in the country. The GEF project consisted two phases. In phase I, there were four components: (1) establishing an ESCO as a mechanism for financing energy efficiency activities in Rivne; (2) implementing a municipal energy saving program, including a pilot project on a typical segment of the municipal district heating system and its users; (3) project replication measures; and (4) monitoring and evaluation. An ESCO was developed through the project implementation, and it operated on a commercial basis under ESPC with its clients (district heating companies and building owners).

In addition, the GEF provided funding to Ukraine for the development of ESCOs. Until November, 2013, the GEF provided a total of US$15,954,000 as grant, and other project stakeholders provided US$38,306,000 as co-financing. However, practice showed that ESCO industry development in Ukraine was not really successful. The UNDP summarized eight issues that caused the failure of ESCO industry in Ukraine (Obrienm 2013). The following are five major issues that are related to the GEF-financed components of the project:

1. The Ukraine ESCO business model was not really an ESCO model recognized by the international standard. For example, the GEF ESCO Rivne project focused on boiler construction and rehabilitation but not on development of a financial mechanism for the energy efficiency market. In Phase I, the Ukraine ESCO used 100 % public funds and grants to build eight new energy-efficient boiler houses in Rivne for district heating, providing approximately 2 % of the municipal heat supply to the market. Phase II of the project was supposed to focus on project financing and ESPC, but these project goals were not achieved. The ESCO Rivne project facilitated installing boilers and heat supply systems. After the construction of the project was over, the ESCO sold steam and hot water to the client's facilities. The ESCO Rivne followed a "build, own, and operate" model, not any ESCO business models introduced earlier in this chapter.

2. Grants prevented the private sector from participating in the investment in energy efficiency in the district heating systems. For instance, in the ESCO Riven project, the ESCO did not use funds from the private sector or home owners to finance energy efficiency projects. The boiler projects were all implemented through grants, which had a perverse impact on the energy supply tariff. In the ESCO business balance sheet, capital investment cost was not shown and therefore was not included into the tariffs, which actually subsidized energy prices in the market and encouraged inefficient use of heat energy.
3. Low energy prices in Ukraine did not incentivize energy efficiency investments. Natural gas prices for households and industry were between US$0.06 and US$0.23 per cubic meter, which were much lower than in Western Europe. Although energy efficiency was a priority in the Ukrainian Energy Strategy 2012, the low domestic prices of energy were a huge barrier to investment in energy efficiency in the country.
4. High interest rate for a commercial loan was another barrier to energy efficiency investment in Ukraine. From 1998 to 2010, interest rates in Ukraine were more than 18 %, which was much higher than the internal rate of return of capital investment (7–8 %) in the energy efficiency market in Ukraine. The Ukraine ESCO business model was not able to attract capital from the private sector.
5. Legislative bias in Ukraine did not encourage shared savings contracts that were successfully used in the USA and China. Due to the lack of legislative mechanisms, municipal clients did not have obligations under ESPCs to pay back an ESCO from achieved energy savings for its investments. The concept of an ESCO and ESPC was not clearly defined and regulated under Ukrainian legislation.

9.2.4 Brazil

In Brazil, there was significant potential to achieve energy savings and reduce both ozone depleting substances gas and greenhouse gas emissions from the buildings market. The GEF project was designed to encourage cross-convention synergies with the Montreal Protocol to include a chiller replacement component, thus contributing to the phaseout of chlorofluorocarbon. The project positively influenced the energy efficiency market and helped chart a less carbon intensive and more sustainable energy consumption path in Brazil and subsequently in the Latin American Region as a whole.

In Brazil, before 2000, there had been almost no encouragement in energy efficiency, except for utility DSM programs. The energy efficiency program under the DSM policy stipulated that utilities had to spend a percentage of their revenue on energy efficiency projects. Additionally, the presidential decree in 2000 required that all federal buildings reduce their electricity consumption by 20 % within two years. In the midst of the 2001 energy crisis, the government showed considerable interest in developing a long-term and market-oriented energy efficiency policy, which was the first energy policy ever where the Brazilian government explicitly recognized the potential importance of energy efficiency services. The promotion of ESCO services by the government became a key element in Brazil's long-term energy efficiency policy.

To further develop energy efficiency policy and help remove barriers to energy efficiency improvement in Brazil, the Brazilian government requested that the GEF support US$13.5 million to implement a capacity building in ESCOs and a financial program that would help realize market transformation. The government also mobilized US$64,825,000 as co-financing for the project. The goal of the project was to influence, transform, and develop the market for energy-efficient building operations in Brazil and move toward a less carbon intensive and more sustainable energy consumption path for the country. At the time when the project was designed, the main barriers included as follows: (1) ESCOs and ESPCs were not known in the energy market; (2) energy efficiency techniques remained poorly understood by building owners/operators/designers in the development and implementation of energy efficiency projects in buildings, particularly in the complex HVAC sector; (3) very few building owners/operators have implemented energy efficiency projects, and they were reluctant to invest in projects with long payback periods; (4) accessing third party financing and performance-based contracts through, for example ESCOs, was complicated for public buildings due to legal barriers and lack of knowledge and understanding by the various public sector stakeholders; and (5) Brazilian financial institutions lacked access to performance risk mitigation options which would enhance their confidence in financing of energy efficiency initiatives.

This GEF-supported project strived to remove these identified barriers through a comprehensive and integrated approach that focused on the following: (1) developing ESCOs and ESPCs in the energy market; (2) building awareness and capacity among various market actors; (3) creating a favorable policy and financing environment to eliminate the barriers specific to the implementation of energy efficiency projects in public buildings and facilities; (4) establishing an integrated approach for potential energy efficiency enhancement in buildings while demonstrating the energy efficiency potential of chlorofluorocarbon-based chillers replacement; and (5) under the lead of the IADB, implementing an energy efficiency guarantee mechanism to reduce the risks perceived in investment in energy efficiency projects. As a result, the project contributed to improving energy efficiency in the Brazilian commercial and public building sectors by saving 4.0 TWh of electricity over 20 years. It is estimated that the project will reduce 12 million tonnes of CO_2 in its 20-year lifetime.

Compared with ESCO industry development in the USA and China, the GEF project in Brazil was considered partially successful. By the end of 2011, there were approximately 75 companies listed as ESCOs with the Brazilian Association of Energy Conservation Companies (ABESCO). Within a core group of eight ESCOs, only four assumed financial risks related to savings performance at a level equal or near to the capital cost incurred to implement the energy efficiency projects and had experience with the financial structuring of projects. Despite partial success in developing the ESCO market in Brazil, barriers remain. Among others, Brazilian ESCOs consider the lack of access to competitive financing as a major impediment to conducting energy efficiency projects.

9.3 Discussions

China, India, Ukraine, and Brazil are all GEF recipient countries, and their experiences and lessons are useful to other countries in similar situations. In China, the ESCO industry has achieved great success and has been moving forward dramatically. In India, the ESCO industry has been progressing, but its speed is not as rapid as that in China. In Brazil and Ukraine, the ESCO business progresses sluggishly. Other countries listed in Table 9.1 have experienced moderate or slow movements in ESCO industry development. It is worthwhile to compare China, India Ukraine, and Brazil and highlight experiences and lessons. The following are the major features in China, India, Ukraine, and Brazil that may affect the development of their ESCO industries.

China, India, and Ukraine used to subsidize domestic energy prices, but Brazil impose high tax in energy prices. During ESCO development, China performed energy pricing reforms, canceled the dual price mechanism for electricity and coal, and improved the pricing system for refined oil products, all of which signaled the speeding up of price and market reforms. In July 2013, China liberalized its gas pricing regime by raising the price of natural gas for non-residential use by 15 %, a forward movement to establish a market-oriented natural gas pricing mechanism that fully reflects supply and demand conditions (Xinhua News Agency 2013). The act was seen as another leap forward after the successful reform of the pricing mechanism of fuel and electricity. In India, energy prices had been controlled by the government. The Indian government realized that market-based pricing and technology were essential to meet India's growing energy demand. Mr. Manmohan Singh, then Prime Minister of India, said in the 8th Asia Gas Partnership Summit, "This [technology and market based pricing] is a combination that is essential to provide rapidly growing economies like ours with energy solutions commensurate with our needs" (Home Business-news 2013). India imports approximately 80 % of oil and oil products in its primary energy supply. Gasoline prices are aligned with world prices, but diesel prices are at least 20 % lower than they should be if they are to be fully aligned with the international market price. Kerosene prices are as much as 70 % lower and LPG prices 50 % lower. This misalignment is not only imposing a burden on the national foreign currency reserve and the oil companies, but it also causes serious distortions for the market to promote energy efficiency in the country. In Ukraine, energy prices are still subsidized to varying extents. Subsidized energy prices do not provide much profit margin for ESCOs to invest in energy efficiency projects and hence prevent ESCOs from developing. In contrast to China, India, and Ukraine, Brazil has one of the most expensive energy (electricity) prices in the world. Even though it has one of the cheapest costs of production (with rich hydropower resources), the electricity price, reaching US$0.15 per kWh (Obrienm 2013), is higher than the prices of many developed countries. The Federation of Industries of Rio de Janeiro, known as Firjan, conducted research in 2011 to find more. In the research report, it was shown that Brazil has 14 taxes over the electric energy bill, which represents not only 17 % of the cost, but also a worldwide record. Further study shows that the tax revenue does not go back to the energy efficiency business. ESCOs do not get incentives to develop energy efficiency businesses. In short, high energy prices with low or no subsidies to energy prices will stimulate ESCO industry development; high taxes on energy consumption without incentive to energy efficiency investments will discourage ESCO industry development.

Government incentives are very important to attract ESCOs. China has established a set of tax incentive policies to catalyze the development of ESCOs, particularly small ESCOs, but India, Ukraine, and Brazil have not developed or implemented such policies yet.

Among China, India, Ukraine, and Brazil, only China used shared savings as the major financial model in ESCO development. In the shared savings model, the major financial resources come from the private sector. The major players of the Indian ESCOs are large energy service providers with their own energy technologies to offer. These companies generate more revenues from selling equipment than from energy management services. Small ESCOs can hardly provide services in the market because of the difficulty to get financial resources. By November 2013, the Ukrainian government had not supported any market-based financial models for ESCOs that are used worldwide. A successful ESCO industry should be developed on the basis of private sector financing, not on the public sector. In Brazil, when ESCOs provide the financing for a project, it is almost always with their own capital. Loans to ESCOs to finance EE projects have been very rare. The lack of access to commercial loans has historically been a key barrier to the expansion of energy efficiency services. There is lack of awareness and right ESCO perceptions from the market in Brazil.

China used public media and Web sites to provide information on ESCOs' services and functions, India did some, but Ukraine and Brazil did little. Lack of public awareness on ESCO was also a crucial barrier to ESCO development in Ukraine.

In addition to differences, there are some common areas among the four countries in ESCO development. First, each of these four countries offers a multi-billion dollar energy efficiency market for ESCO industry development. Second, there are still many barriers to ESCO growth in these countries. These barriers can be briefly summarized as follows:

1. Lack of awareness: Many energy users have a misunderstanding of ESCOs. They think that the ESCOs make profits at the expense of the energy consumers. They do not realize that it is a win-win situation for ESCOs to provide services to clients of the energy systems.

2. Difficulty to access to finance: Energy efficiency projects are mostly capital intensive. ESCOs are generally dependent on either prospective clients or commercial banks for funding. The banks often lack awareness on the savings potential of the projects resulting in higher interest rates and capital costs. This is particularly the case with small ESCOs like in India and Brazil.
3. Technology preference over management service: The ESCO industries in India, Ukraine, and Brazil were dominated by ESCOs which focused on selling technologies, not on providing energy management services. Open, competitive bidding for technologies was not seen in the ESCO industry. The clients perceived ESCO services to be biased in using technologies.
4. Savings monitoring and verification: The energy savings are measured based on the project baseline scenario without ESCO involvement and project scenario with ESCO involvement. Monitoring and verifying energy savings from ESCO projects is difficult. Usually, the measured results of energy savings by the ESCOs and the clients are not identical, which often becomes a point of dispute between the ESCOs and the clients. There is a need of independent third parties to undertake energy savings monitoring and verification for the ESCO projects. By December 2013, none of the four countries have developed such nationally certified professional third party companies for monitoring and verifying energy savings in ESCO industry.

9.4 Conclusions

ESCOs and ESCO financing can effectively unlock barriers to energy efficiency financing in developing countries. Since the early 1990s, the GEF has financed 39 ESCO projects in 25 countries and regions. Some of these projects were very successful, some were partially successful, and some were unsuccessful. In one ESCO project in China, for example, the GEF provided a US$16.9 million grant, leveraged over US$800 million from local banks and the private sector for more than 170 energy efficiency and renewable projects that will mitigate more than 19 million tonnes of CO_2 per year. But other ESCO projects in other countries were not as successful as in China. The ESCO industries in these countries were relatively underdeveloped, largely due to low energy prices, weak legal and regulatory frameworks, lack of local financial market, administrative barriers, and low awareness and skepticism of the clients. Market-based energy prices, private sector-based financial models, and moderate tax incentives for new ESCOs were major factors that facilitated the success of the Chinese ESCO industry. The successful experience of China may be useful to other countries for their ECSO industry development.

This chapter concludes that countries and agencies need to consider the following instruments when they are developing ESCO projects: (1) initiatives of the national government policy to stop energy subsidies and reform energy pricing, (2) establishment of a real market-based financial mechanism for ESCOs,

(3) involvement of the private sector in project co-financing, (4) part of government revenue from energy tax should be invested back energy efficiency market and create incentives to ESCOs, and (5) development of government cooperate tax exemption incentive to ESCOs.

References

Bullock C, Caraghiaur G (2001) A guide to energy service companies. Fairmont Press, Lilburn

Delio et al (2010) Powering up: the investment potential of energy service companies in India. Available at http://pdf.wri.org/powering_up_full_report.pdf. Cited 12 Jan 2013

Home Business-news (2013) Prime Minister backs market based price for gas, energy, Hindustan Times Correspondent. Available at http://www.hindustantimes.com/business-news/pm-backs-market-based-price-for-gas-energy/article1-1158821.aspx. Cited 3 Dec 2013

IFC—International Finance Corporation (2013) China utility-based energy efficiency finance program (CHUEE). Available at http://www.ifc.org/wps/wcm/connect/0f680e004a9ad992af9fff9e0dc67fc6/Chuee+brochure-English-A4.pdf?MOD=AJPERES. Cited 27 Nov 2013

Obrienm J (2013) Experiences in implementing ESCO projects, policies and financing schemes for energy efficiency in buildings. Presented at a workshop, Belgrade, 18–19 Jun 2013

Weiss D (2013) The U.S. ESCO industry. Presented at the 4th China and U.S. Energy Efficiency Forum, Arlington 24 Sep 2013

World Bank (2008) Implementation completion and results report, Loan No. 45710, 33960, GEF Grant No. 20169, Report No: ICR0000910. Available at the GEF PMIS database

Xinhua News Agency (2013) Insight: China's market reforms to upgrade economy. Available at http://news.xinhuanet.com/english/indepth/2013-11/04/c_132858139.htm. Cited 4 Dec 2013

Zhao M (2013) ESPC and ESCO development in China. Available at www.emca.cn. Cited 3 Dec 2013

Chapter 10
Energy-Efficient Technologies

Abstract Nowadays, research, development, deployment, and investment in energy-efficient technologies take place in many areas including lighting, household appliances, building envelope, windows, doors, heating, ventilation, air-conditioning, heat exchangers, working fluids, geothermal heat pumps, water heating, sensors and controls designed to measure building performance, smart grids, industrial process, electrical motors, and energy-efficient transport. This chapter briefly introduces some technologies that are related to these areas including energy-efficient lighting, refrigerators, electrical motors, and vehicles. It also presents policies to facilitate investments in several most common energy-efficient technologies and provides economic and technical guidance on choosing and investing in energy-efficient technologies.

10.1 Introduction

Energy-efficient technologies refer to technologies that reduce the amount of energy required to provide goods and services. For example, home insulation technology allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Fluorescent light or natural skylight technologies reduce the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Solid-state lighting (SSL) technology uses 10 % the energy of incandescent lights for the same amount illumination and may last 10 times longer. Improvements in energy efficiency are generally achieved by adopting a more efficient technologies or production processes or by application of commonly accepted methods to reduce energy losses (IEA 2007; Diesendorf 2007). Energy-efficient technologies are related to specific time periods and geographic regions, and government policies. Various governments have invested a tremendous amount of capital in promoting energy-efficient technologies, such as

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_10

1. Energy-efficient refrigerators, washers, dryers, and other appliances;
2. Parts of the building envelope, including insulation, roofing and attics, foundations, and walls;
3. Window, skylight, and door technologies, such as highly insulating windows, glazing and films, window frames, and day-lighting and shading technologies;
4. HVAC, heat exchangers, working fluids, geothermal heat pumps, and other space heating and cooling;
5. Water-heating equipment including heat pump water heaters and solar water heaters;
6. SSL, including LED and organic light emitting-diode (OLED) lighting;
7. Sensors and controls designed to measure building performance;
8. Building energy modeling software;
9. Industrial process and electrical motors; and
10. Energy-efficient transport.

This chapter reviews some of the aforementioned technologies.

10.2 Energy-Efficient Technologies in Lighting

10.2.1 Technology Development

In 2013, electricity consumption from lighting accounts for about 19 % of the global electricity, equivalent to 8.9 % of worldwide energy consumption. The dollar value of the consumed energy accounts for 0.63 % of the global GDP. By 2050, if SSL technology is widely adopted, the global electricity consumption for lighting will be at the same level as in 2005. Therefore, the usage of more energy-efficient lighting products can enhance the efficiency of energy use in lighting. SSL technologies have a great potential to reduce energy consumption in lighting and GHG emissions.

SSL in the form of LEDs was first applied commercially in the 1960s, but only in recent years has it matured sufficiently that people are now considering it as a potentially serious contender for general lighting applications. The light output of early LED devices was very low, and the efficacy was extremely poor; however, in the intervening five decades LED, efficacy has been doubling every two years and in recent years surpassed that of incandescent lamps, halogen lamps, and fluorescent lamps (Table 10.1). Furthermore, manufacturers of SSL devices have set a target of 160 lumens/watt (lm/W) by 2015, which would be more than ten times as efficient as incandescent lamps and 2.5 times more than CFLs. This section reports on the state of the SSL technology and its potential and examines the issues that may determine whether SSL will herald a new revolution in lighting.

Table 10.1 Luminous efficacy table

Lumens (lm)	Incandescent light bulb watts (W)	Fluorescent/LED watts (W)
375	25	6.23
600	40	10
900	60	15
1125	75	18.75
1500	100	25
2250	150	37.5
3000	200	50

Source http://www.rapidtables.com/calc/light/how-lumen-to-watt.htm

10.2.2 Physical Principles and Performance Characteristics of SSL Technologies

10.2.2.1 Physical Principles and Types of LED

LEDs are the primary SSL technology (Fig. 10.1). Unlike computer chips, which are based on doped silicon, LED semiconductors are crystals comprised of combinations of typically two or three inorganic elements, such as gallium phosphide or gallium indium nitride. When an electric field is applied to the material, negatively

Fig. 10.1 A modern LED. *Source* Photographed by authors

charged electrons and positively charged holes (positively charged electron vacancies) are produced and exist at different energy levels separated by a "band gap." When these subsequently recombine, the released band-gap energy is converted into a photon of light with a frequency, and hence color, that is, equivalent to the band-gap energy. This results in the emission of light in a very narrow spectrum. Because the light is narrow band, an SSL is much higher than an incandescent lamp in light-emission efficiencies. By contrast, light from LEDs is monochromatic, which means that intermediate processing is needed if white light is to be produced.

When their increasingly superior efficacy and lower operating costs are taken into account, LEDs begin to look more viable. The reality of general illumination markets is that product market penetration is highly sensitive to first cost and much less so to ongoing costs. It is thought that costs need to come down by at least an order of magnitude if LEDs are to become competitive for general lighting purposes. Ideally, LEDs would attain a cost of US$2 per kilo-lumen or lower.

Some of the high first cost of LEDs is associated with their relative novelty and ongoing rapid development. Despite the long history of LEDs, it is only in the last few years that they have begun to reach a performance level where they might be suitable for general illumination applications. Expenditure on research and development (R&D) in LEDs is still high. Costs should fall progressively as the technology matures, production is standardized and scaled up, and manufacturers improve their production facilities.

10.2.2.2 LED Efficiency

There are at least four factors affecting energy efficiency of LED lamps. The first is power source. Commercial power is distributed as an alternating current (AC), high-voltage source, but LEDs require low-voltage directing current power. Power conversion is necessary for LEDs in commercial and home use. Using a transformer to reduce the voltage followed by rectification inevitably leads to some loss of power.

The second factor is LED operation. There are inherent electrical losses associated with contact resistance, the bulk resistivity of the semiconductor layers themselves, and band-bending effects that must be overcome to transport electrons and holes into the active region where they recombine to produce photons. The most obvious impact of the sum of these effects is that the forward voltage of LEDs exceeds the photon energy. For example, a typical blue LED with a nominal emission wavelength of 460 nm (nm) will have a forward voltage between 3.1 and 3.6 V. Comparing this with the 2.7-eV energy of photons with a wavelength of 460 nm reveals internal electrical efficiencies of 75–87 %. The more mature technologies associated with LEDs allow higher internal electrical efficiencies in excess of 90 %.

The third is the internal quantum efficiency of LEDs, which is a measure of the fraction of photons produced for each electron injected into the device. Internal quantum efficiencies of nearly 100 % have already been reported for longer wavelength LEDs.

The final factor with LED efficiency is an optical problem directly resulting from the high refractive index of the compound semiconductor materials used to make LEDs. This leads to large reflective losses at the interface between the LED die and the encapsulating medium. Various schemes either have been or are in the process of being developed to reduce these reflective losses.

The overall efficiency of any LED is the product of all of these factors. If each of the factor causes 10 % loss, the LED will have an efficacy of 90 % × 90 % × 90 % × 90 % = 65.61 %. Although many assumptions have gone into the calculation of this efficiency factor and many solid-state-lighting road maps call for even higher efficiencies, it should be noted that the highest recorded wall plug efficiency for any LED is 45 %, so increasing efficiency to 65.6 % at all wavelengths would be an achievement. This efficiency is used as the criterion for the practical efficacy of LED systems using AC power.

10.2.2.3 Longevity

An undoubted major advantage of LEDs is their very long life span, which can be in excess of 50,000 h. LEDs will last for a very long time without a catastrophic failure because there is no filament or cathode to burn out. Instead of suddenly ceasing to emit light, their performance will gradually degrade over time. High-quality LEDs are predicted to deliver more than 60 % of the initial light intensity after 50,000 continuous operating hours and to continue working for up to 100,000 h (some 100 times longer than a standard incandescent lamp). With such long operational life spans, it is impractical to measure the rated life of LEDs in the same way as for conventional lamps. Rather, the few tests that have been done have focused on the rate of performance degradation over time. Not surprisingly, LED lifetime and performance degradation are sensitive to heat, and this is a key reason why such efforts must be made to remove heat from the device.

10.2.2.4 Cost

Whatever the current technical strengths of LEDs, the final determinant of their suitability for any given application is their cost. For most applications, this is still high, although they have become economically viable for a growing range of important niche markets. The first costs of LEDs are high relative to standard illumination devices. If a typical incandescent light bulb costs about US$1 per kilo-lumen, standard LEDs currently cost about US$5–10 per kilo-lumen (5 or 10 times as much). If the cost of ownership is considered, LEDs begin to look much more attractive. Their very long lifetimes would allow them to compete with incandescent sources on bulb costs alone where a zero-rated discount rate applied, and if the cost of bulb replacement labor is included, they become even more attractive.

10.2.2.5 The LED Outlook

LED manufacturers have forecast that LED lights, now commercially available at 30–90 lm/W, will ultimately meet and exceed the efficacy of other white-light sources, achieving a goal of between 150 and 200 lm/W, most efficient lighting technology as of 2014. In principle, there are no known reasons why this cannot be achieved, and the technology is progressing to overcome barriers that currently limit the performance of these devices; however, the barriers are still very significant, and it is not yet clear how viable LEDs will ultimately become as white-light sources.

10.3 Energy-Efficient Appliance: Refrigerator Technologies

10.3.1 Energy-Efficient Refrigerators

Common household refrigerators used to consume a significant amount of energy. The demand for dramatic improvements in efficiency began in response to the energy crises of the 1970s when refrigerators typically cost about US$1,300 per unit (adjusted for inflation). In conjunction with the US Environmental Protection Agency, the US Depart of Energy developed the ENERGY STAR® program to help American consumers save money and protect the environment through energy-efficient products and practices. Refrigerators that perform above and beyond the minimum energy standards qualify for the ENERGY STAR label; this in turn primes the market for continued efficiency improvements and helps motivate consumers to care about energy use. Manufacturers consistently respond with new innovations that enable their products to meet or exceed the new energy efficiency requirements. In 2014, refrigerators use only about 25 % of the energy required to power models built in 1975.

10.3.2 Efficiency Climbs with Computer Technologies

Manufacturers are offering more energy-efficient refrigerators without jacking up the prices. Several innovative areas are facilitating energy efficiency in refrigeration technology. First, innovative compressors are pumping up efficiency. The Samsung RF266AE bottom-freezer, for example, gets a high mark for efficiency partly because of its variable-speed compressor. Second, application of computer in refrigerators is increasing energy efficiency. An optimized compressor with a computer chip raises the efficiency of the Whirlpool Gold G9RXXFMW top-freezer in 2014.

10.4 Energy-Efficient Vehicles

In a typical vehicle, only about 14–26 % of the energy from fuels is used to move the car down the road, depending on the drive cycle. The rest of the energy is lost to engine, and driveline inefficiencies are used to power accessories. These losses include the following: (1) engine efficiency loss: 28–30 %, (2) parasitic (water pumps) loss: 5–6 %, (3) power to wheels (wind resistance, rolling resistance, braking): 17–21 %, (4) drivetrain loss: 5–6 %, and (5) idle loss: 3 %. The potential to improve fuel efficiency with advanced technologies is enormous in vehicles.

There is a huge gap in terms of energy difference between efficient vehicles and inefficient ones. In 2014, the most energy-efficient vehicle could run at 107 miles per gallon (MPG), while the most inefficient vehicle could run at 13 MPG (US EPA 2014). Table 10.2 shows various vehicles and their energy efficiencies.

There are many technologies and techniques currently available that can significantly increase fuel efficiency for vehicles. These technologies, such as turbocharging and direct fuel injection, are more readily associated with vehicle performance, but they also provide significant improvements in fuel economy.

Innovative fuel efficient technologies are generally pushed by the government. In the USA, for example, due to federal government standards set in 2010, the national average for model year 2013 vehicles must meet 30.5 MPG, reaching 34.1 MPG in 2016. New cars and light trucks in 2025 must meet a fleet average of 54.5 MPG. More efficient cars will dramatically cut oil dependence and put money in drivers' pockets: The 2017–2025 standards are expected to save 163–170 billion gallons of fuel and generate over US$450 billion in net economic benefits in the USA.

Energy-efficient technologies have been widely researched, developed, and applied in vehicles. These include (1) continuously variable transmissions, (2) cylinder deactivation, (3) direct fuel injection, (4) integrated starter/senator, (5) turbocharging and supercharging, (6) variable valve timing and lift, (7) using

Table 10.2 2014 most and least efficient vehicles

EPA vehicle class	Vehicle description	Fuel economy
Efficient cars		
Seaters	Smart Electric Drive Convertible A-1, 55 kW DCPM, Electric Vehicle	107[a]
Minicompacts	Fiat 500e A-1, 82 kW AC Induction, Electric Vehicle	116[a]
Least efficient cars		
Two seaters	Bugatti Veyron, 16 cyl, 8.0 L, Auto (AM-S7)	10
Midsize	Bentley Mulsanne, 8 cyl, 6.8 L, Auto (S8)	13
Small station wagons	Cadillac CTS Wagon, 8 cyl, 6.2 L, Auto (S6)	14

[a] This is an electric vehicle. Since electricity is not measured in gallons, a conversion factor is used to translate the fuel economy into miles per gallon of gasoline equivalent (MPGe). *Source* (U.S. EPA 2014)

light materials for vehicle weight reduction, (8) aerodynamic efficiency and vortex generators, and (9) wheels. The following sections describe these features in more detail:

1. Continuously variable transmissions do not have a fixed number of gears. Instead, they employ a pair of variable diameter pulleys which are linked by chain or belt, creating an infinite amount of gear ratios between a preset minimum and maximum. This continuous variability limits the amount of revolutions per minute for any given speed and, therefore, reduces fuel consumption.
2. Vehicles equipped with cylinder deactivation technology have the ability to deactivate half of their engine's cylinders while cruising and reactivate them under heavy acceleration. Engines with six or more cylinders can use this technology without a noticeable drop in performance.
3. In traditional engines, fuel and air are mixed outside the cylinder. In engines equipped with direct fuel injection, fuel is injected directly into the barrel of the cylinder, allowing for greater control of the fuel–air mixture and more efficient combustion.
4. Integrated starter/senator technology allows engines to be shut down instead of idling for short stops, such as red lights, and instantaneously restarted under acceleration.
5. Turbochargers are fans powered by engine exhaust that forces compressed air into the engine cylinders. Similarly, superchargers use fans to force compressed air into the cylinders, but they are powered by the engine itself. The compressed air improves combustion efficiency by allowing more fuel to be burned per piston stroke. Engines equipped with either of these technologies produce more power and use less fuel than engines of the same size without them.
6. Valves control the flow of fuel and air into and the flow of exhaust out of the cylinders in the engine. In traditional vehicles, the distance a valve travels remains constant at all speeds. Variable valve timing and lift allows the distance the valves travel to change in accordance with the speed of the engine, which improves engine efficiency and hence vehicle efficiency.
7. Using carbon fiber and lighter metals, manufacturers have managed to reduce the weight of cars while maintaining durability and strength. Engines in lighter vehicles operate more efficiently than engines of the same size in heavier vehicles.
8. In terms of aerodynamic efficiency, vehicles that ride low on their wheels are exposed to less drag than ones that do not. Since the gap between the bottom of the car and the road is smaller, less air is exposed to the rough underside of the vehicle and the bottom of the tire tread. Adding or repairing an existing broken air dam (a metal or plastic device fitted below the front bumper designed to deflect air away from the bottom of the car) can reduce drag and increase fuel mileage. Vortex generators are small, delta-shaped devices that can be placed on the roof of a vehicle, just in front of the rear window. The aerodynamic shape of the generators creates vortices that reduce drag by causing the air to flow along the rearward surfaces of the car, such as the rear windshield and trunk lid,

instead of flowing above them. They lessen net drag by reducing the area of separated airflow behind a vehicle at speed. Spoilers, depending on their size, shape, and positioning, also can help reduce drag.

9. Thinner and smaller wheels reduce the surface area that a vehicle needs to push through the air and reduce road friction, decreasing drag, and increasing fuel mileage. In addition, fully closed, concave rims are more aerodynamic than open rims. Low rolling resistance tires also aid fuel efficiency.

10.5 Energy-Efficient Electric Motors

10.5.1 Definition

The efficiency of an electric motor is the ratio of mechanical power output to the electric power input, usually expressed as a percentage. A more efficient motor can accomplish more work per unit of electricity consumed. Considerable variation exists between the performance of standard and energy-efficient motors. Figure 10.2 shows an example of the distribution of efficiency of electric motors. Improved design, better materials, and advanced manufacturing techniques enable motors more efficient.

Besides saving energy, efficient motors offer other benefits. Because they are constructed with improved manufacturing techniques and superior materials, energy-efficient motors usually are longer in insulation and bearing lives, lower in waste heat output, less vibration, and less impact on the electricity grid. All of these characteristics increase reliability.

To be considered energy efficient, a motor's performance must be equal or exceed the nominal full-load efficiency values or standards published or provided by a national standard of a country. In the USA, for example, the standard is

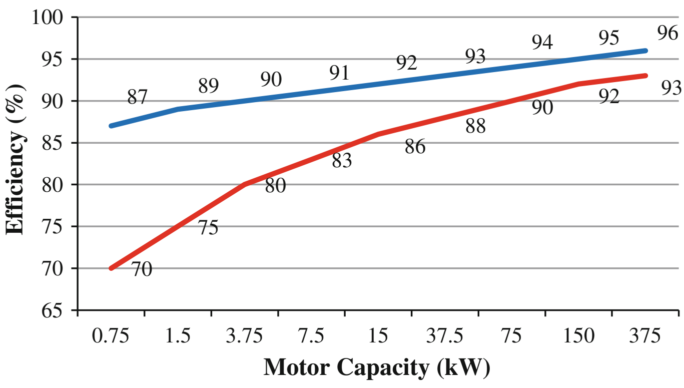


Fig. 10.2 Envelope of efficiency of electric motors. *Source* Developed from authors' experience and data

published by the National Electrical Manufacturers Association MG-1 or NEMA MG-1. Specific full-load nominal efficiency values are provided for each kilowatt, enclosure type, and speed combination.

10.5.2 Efficiency Values Used to Compare Motors

A consistent measure of efficiency should be used to compare motor efficiencies. Nominal efficiency, which is the best measure, is an average value obtained through standardized testing of a population of motors. Minimum guaranteed efficiency, which is based on nominal efficiency, is slightly lower to take into account typical population variations. Minimum guaranteed efficiency is also less accurate, because the value is rounded. Other efficiency ratings, including apparent and calculated, should not be used. In the USA, the recognized motor efficiency testing protocol is the Institute of Electrical and Electronics Engineers 112 Method B, which uses a dynamometer to measure motor output under load. Different testing methods that yield significantly different results are used in other countries.

10.5.3 Use Energy-Efficient Motors

Energy-efficient motors should be considered in the following circumstances:

1. For all new installations;
2. When purchasing equipment packages, such as compressors, HVAC systems, and pumps;
3. When major modifications are made to facilities or processes;
4. When old motors fail function;
5. To replace oversized and under-loaded motors; and
6. As part of a preventive maintenance or energy conservation program.

The cost-effectiveness of an energy-efficient motor in a specific situation depends on several factors, including motor price, efficiency rating, annual hours of use, energy rates, costs of installation and downtime, user's payback criteria, and the availability of utility rebates.

10.5.4 Cost-Effectiveness of Motors

The extra cost of an energy-efficient motor is often quickly repaid in energy savings. Each point of improved motor efficiency can save significant amounts of money each year. In typical industrial applications, energy-efficient motors are cost-effective when they operate more than 4,000 h a year, given a 2-year simple payback criterion.

For example, with an energy cost of US$0.04/kWh, a single point of efficiency gain for a continuously operating 37.5 kW motor with a 75 % load factor saves 4,079 kWh, or US$163 annually. Thus, an energy-efficient motor that offers four points of efficiency gain can cost up to US$1,304 more than a standard model and still meet a 2-year simple payback criterion (4*2*US$163 = US$1304). A utility rebate program would further enhance the benefits of an energy-efficient motor. Whenever possible, obtain actual price quotes from motor distributors to calculate simple payback periods. Motors rarely sell at full list price. Users can typically obtain a 20–60 % discount from vendors, with specific prices depending on the distributor's pricing policies, the number and type of motors which the users buy, and fluctuations in the motor market. The following three techniques can help customers determine whether an energy-efficient motor is cost-effective:

Use the following formulas to calculate the annual energy savings and the simple payback period from selecting a more energy-efficient motor. The simple payback period, as showed in the chapter of energy efficiency cost-effective test of this book, is defined as the number of years required for the annual savings to cover the initial or incremental cost.

Annual energy savings

$$\mathrm{AES} = \mathrm{kW} \times \mathrm{LF} \times \mathrm{Hr} \times C \times \Delta E \tag{10.1}$$

where

AES Expected annual savings (US$)
kW Motor rated capacity in kilowatts
LF Load factor (percentage of full load)
Hr Annual operating hours
C Average energy costs (US$/kWh)
ΔE Gain of efficiency (Efficiency an efficient motor less the efficiency of a standard motor) %

The simple payback period can be calculated as follows. For a new motor purchase, the simple payback is the price premium minus any utility rebate for energy-efficient motors, divided by the annual dollar savings:

$$\mathrm{SPP} = \frac{\text{Price premium} - \text{Utility Rebate}}{\text{Annual Savings}} \tag{10.2}$$

When calculating the simple payback for replacing an operating motor, the full purchase price of the motor plus any installation costs should be included. The formula becomes

$$\mathrm{SPP} = \frac{\text{Motor price} + \text{Installation Cost} - \text{Utility Rebate}}{\text{Annual Savings}} \tag{10.3}$$

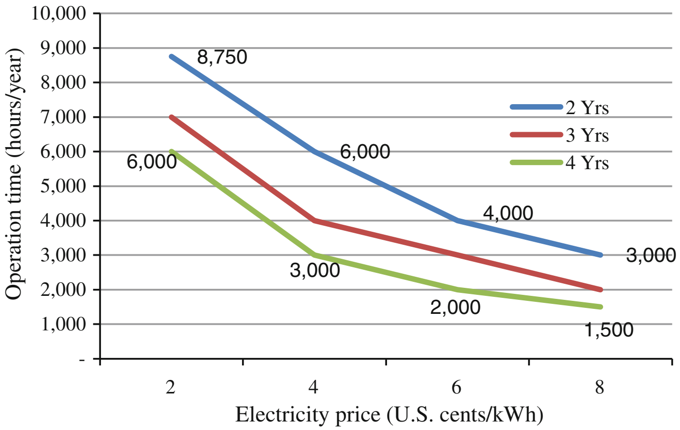


Fig. 10.3 Minimum hours of use to meet simple payback criteria. *Source* Developed from authors' data

The minimum number of hours a year a motor must be used at various energy prices in order to obtain a 2-, 3-, and 4-year simple payback periods. This technique is less accurate than a more detailed analysis. The calculation of values for Fig. 10.3 assumes that an energy-efficient motor has a 15–25 % price premium with no utility rebate, and it ignores other benefits of energy-efficient motors. A lower price premium, a rebate program, or reliability benefits make energy-efficient motors even more cost-effective. Choose a new energy-efficient 1–75 kW motor if it will be used more than the indicated number of hours each year.

10.5.5 Deal with Failed Motors

Although failed motors can usually be rewound, it is often worthwhile to replace a damaged motor with a new energy-efficient motor to save energy and improve reliability. When calculating operating costs for rewound motors, one should deduct one efficiency point for motors exceeding 30 kW and two points for smaller motors. Have motors rewound only at reliable repair shops that use low temperature (under 370 °C) bake-out ovens, high-quality materials, and a quality assurance program based on ISO-9000. Ask the repair shop to conduct a core loss or loop test as part of their rewind procedures. Select a new energy-efficient motor under any of the following conditions:

1. The motor capacity is smaller than 30 kW;
2. The cost of the rewind exceeds 65 % of the price of a new motor; and
3. The motor was rewound once before 1980.

10.5.6 Motor Size to Consider

Motors should be sized to operate with a load factor between 65 and 100 %. Common practice of oversizing results in less efficient motor operation. For example, a motor operating at a 35 % load is less efficient than a smaller motor that is matched to the same load. Of course, some situations may require oversizing for peak loads, but in such cases, alternative strategies should be considered, such as a correctly sized motor backed up with a pony motor.

10.5.7 Operating Speed

Induction motors have an operating speed that is slightly lower than their rated synchronous speed. For example, a motor with a synchronous speed of 1,800 rpm will typically operate under full load at about 1,750 rpm. Operating speed, full-load rpm, is stamped on motor nameplates. The difference between the synchronous speed and the operating speed is called slip. Slip varies with load and the particular motor model.

Every pump and fan has a design speed. Centrifugal pump and fan loads are extremely sensitive to speed variations; an increase of just 5 rpm can significantly affect the pump or fan operation, leading to increased flow, reduced efficiency, and increased energy consumption. Whenever a pump or fan motor is replaced, be sure to select a model with a full-load rpm rating equal to or less than that of the motor being replaced.

10.5.8 Inrush Current

Energy-efficient motors feature low electrical resistance and thus exhibit higher inrush currents than standard models. The inrush current duration is too short to trip thermal protection devices, but energy-efficient motors equipped with magnetic circuit protectors can sometimes experience nuisance starting trips.

10.5.9 Periodic Maintenance

It is important to maintain motors according to manufacturers' instructions. Although energy-efficient motors with higher temperature-rated insulation may be able to handle higher temperatures and other abuse, there is no reason to reduce maintenance. Motors should have good ventilation and be periodically inspected for increased vibration or power supply problems.

10.6 Conclusions and Looking Ahead

New energy technologies and innovative designs are combining to create the next generation of energy-efficient technologies to meet the increasing saving targets of countries. Continued effort in research, development, and deployment to promote new energy-efficient technologies can help achieve large energy savings. Future energy-efficient technology research, development, and deployment will likely aim at:

1. Improving efficiency, performance, lifetime, and quality of lighting from light-emitting diodes through SSL research;
2. Improving the energy efficiency of appliances;
3. Promoting energy-efficient transportation technologies including high-speed trains and electric vehicles, hybrid cars, and fuel cell vehicles;
4. Reducing the amount of energy lost through the building envelope and windows, skylights, and doors by developing innovative materials and equipment;
5. Increasing the cost-effectiveness and energy efficiency of building space heating and cooling and water-heating technologies;
6. Developing sensors and controls to help building operators better adapt energy use to environmental conditions; and
7. Developing building energy modeling software that allows researchers and building professionals to model building energy and water use and make recommendations for improving efficiency.

Future energy-efficient market development may include the following:

1. Demonstrating the importance and impact of improving residential and commercial building energy efficiency;
2. Providing partnership opportunities to manufacturers and researchers looking to develop energy-efficient technologies;
3. Encouraging stakeholders to participate in meetings and help review applications;
4. Encouraging college students to develop innovative designs for energy efficiency improvement; and
5. Promoting regional job creation and economic growth through the adoption of innovative energy-efficient technologies.

References

Diesendorf M (2007) Greenhouse solutions with sustainable energy. UNSW Press, Australia, p 86

IEA—International Energy Agency (2007) Lights labour's lost. OECD, Paris. https://www.iea.org/publications/freepublications/publication/name,3644,en.html

U.S. EPA—United States Environment Protection Agency (2014) Most and least efficient vehicles. http://www.fueleconomy.gov/feg/best-worst.shtml. Cited on 4 May 2014

Chapter 11
Energy-Efficient Urban Transport

Abstract Urban transport alone consumes nearly 8 % of world energy use, and it is one of the largest contributors in both global and local pollutions. Urban transport energy efficiency is to maximize travel activity with minimal energy consumption through combinations of land-use planning, transport modal share, energy intensity reduction, fuel-type switching, and replacement of information transmission for vehicle travels. Different kinds of cities have different barriers to energy-efficient transport modes. To achieve urban transport efficiency in energy use, government policies are needed to unlock these barriers in the market. Sustainable energy efficiency transport system needs both public and private sector investments. PPPs can greatly facilitate low-carbon and high energy-efficient transportation technologies. Substitution of moving information for moving people can greatly improve energy efficiency in the transport sector. A future efficient transport system in urban area will be in affordable, frequent, and seamless public transport that integrates information technologies, trains, bicycles, taxies, and sidewalks.

11.1 Introduction

Being an energy-intensive sector, transport currently accounts for half of global oil consumption and nearly 20 % of world energy use, of which approximately 40 % is used in urban transport alone (IEA 2013). The IEA's scenario showed that urban transport energy consumption will double by 2050, despite ongoing vehicle technology and fuel-economy improvements. While increased mobility brings many benefits, the staggering rate of this increase creates new challenges. Urgent energy efficiency policy attention will be needed to mitigate associated noise, air pollution, congestion, climate, and economic impacts.

Low-carbon emission transportation, with energy-efficient and renewable energy technologies and greening initiatives in the planning can substantially reduce GHG emissions and other potential negative environmental impacts. Demonstrations of energy-efficient transport and sustainable urban planning also help countries

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_11

familiarize themselves with the real-world benefits and logistics of using environmentally sound technologies and practices.

Urban transport energy efficiency can be defined as the maximization of travel activity with minimal energy consumption through combinations of land-use planning, transport modal share, energy intensity reduction, fuel-type switching, and replacement of vehicle travels with information transmission.

There are various approaches to improving urban transport energy efficiency. For example, cities with high private vehicle travel activity can promote shifts to non-motorized transport (e.g., bicycles and walking) and public transport modes. They can also require higher vehicle fuel-economy standards and establish stronger land-use and vehicle-use regulations.

Some cities face difficult challenge of maintaining economic competitiveness, and improving and expanding municipal services in the face of limited budgets. Energy efficiency can help these cities relieve some of the budgetary pressure by reducing energy costs, thus freeing resources for municipal services. Energy efficiency can also help improve the quality of services, such as improved lighting, transport, and building maintenance.

11.2 Barriers to Urban Transport System Efficiency

There are many barriers to promoting public green transport. These include policy and market failures, lack of access to financing, political resistance, and resistance from administrative and legal systems.

Policy and market failures: Subsidies for fossil fuels and incentives for construction in greenfield areas for highways can encourage markets to favor the use of private vehicles. Appropriate policies should recommend countries to eliminate these subsidies and incentives and set taxation systems to tax fuel and land use for private transportation. These polices should take into account negative impact of CO_2 emissions, local pollution caused by travel.

Lack of access to financing public transport project: An urban mass transport system, such as a subway system, requires a large amount of capital investment. Municipal budget constraints make it necessary to consider a variety of funding mechanisms, including revenues from road pricing such as toll roads, congestion charges, and parking levies. Forms of agreements and PPPs, including municipal support agreements and build–operate–transfer concessions can also be useful structures for financing municipal public transport projects.

Other barriers: Political resistance, administrative and legal resistance, public opposition, institutional capacity, and jurisdictional issues can all cause barriers to improving urban transport system efficiency.

Successful policies to overcome these barriers take into account the interface of land-use and travel network development. Policy makers need to forecast travel demand from the society, evaluate different travel modes, and then develop policies for the society.

11.3 Government Policy Role to Remove Barriers

The IEA (2013) identified measures to increase energy efficiency in the transport sector that included improvements in vehicle and fuel technologies, policies to shift travel to more efficient modes and measures to avoid motorized travel when possible. These measures contributed to what was known as an "avoid, shift, and improve" approach to achieve energy security and climate change targets.

"Avoid" policies address transport energy use and emissions by slowing travel growth via city planning and travel demand management (Table 11.1). "Avoid" policies also include initiatives such as logistics technology to decrease travel volume by finding shorter and more efficient routes.

"Shift" policies enable and encourage movements from private motorized travel to more energy-efficient modes, such as public transit, walking and cycling, and freight rail. Increases in affordable, frequent, and seamless public transport can encourage greater use of public transport over private vehicles (Table 11.2). Both "avoid" and "shift" policies can help to achieve significant efficiency improvements and emissions abatement.

"Improve" policies can reduce energy consumption and emissions through the introduction of efficient fuels and vehicles (Table 11.3), when motorized travel is necessary. "Improve" policies include tightened fuel-economy standards and increased advance vehicle technology sales (e.g., clean diesel trucks and hybrid and plug-in electric cars).

Potential Benefits of "*Avoid, Shift, and Improve*" *Policies*

The IEA (2013) estimated that "avoid" and "shift" policies have the potential to reduce approximately US$30 trillion (in 2010 price) of expenditures on vehicles, fuels, and infrastructure by 2050. These savings will be achieved with investment in 200 billion km of new rail track and a tenfold increase in BRT networks in urban areas across the world. A combined "avoid," "shift," and "improve" approach could lower global transport expenditures by nearly US$70 trillion by 2050.

Table 11.1 "Avoid" objectives and examples of policy responses

Objectives	Policies
To reduce trip length	High-density, mixed land-use development
	National/regional urban planning guidelines
	Subsidies/tax incentives for low-carbon transport city design/planning
To reduce the need or desire to travel	Information tools to raise awareness of real travel costs
	Mobility management and marketing
	Promotion of car pooling
	Freight logistics
	Parking standards and fees/levies

Table 11.2 "Shift" objectives and examples of policy responses

Objectives	Policies
Shift passenger travels to public transport and non-motorized technology (NMT) modes; prevent passenger shifts to motorized transport	Integrated public transit and land-use planning
	Improved bus routes and services
	Parking restrictions
	Pricing strategies, such as bidding system for vehicle plates, and fuel/vehicle taxes
	Traffic restrictions and travel bans in city centers
	Road space allocation: dedicated lanes for buses, bus rapid transit (BRT), and bicycles. More sidewalks, crossings, and overpasses for pedestrians
	Congestion and road charges
Shift land transport to water transport	Standards for size and weight of large vehicles on roads

Table 11.3 "Improve" objectives and examples of policy responses

Objectives	Policies
Reduce energy use and emissions	Vehicle fuel economy or emission standards
	Speed limits
	Planning of low-carbon electricity generation and smart grids for electric vehicle charging stations
	Eco-driving
Improve fuel and vehicle technologies	Vehicle feedback instruments
	Fiscal incentives for efficient/lower carbon vehicles
	Subsidies for alternative fuels
	Vehicle fuel-economy/environmental performance labeling

Four Common City Transport Contexts

Policies to put in place to improve energy efficiency of an urban transport system depend on the type of cities, transport needs, and challenges. To assist policy makers, this chapter has devised a typology of four common city transport contexts including developing cities, sprawling cities, congested cities, and multi-modal cities. The four contexts describe some of the general travel trends and transport system issues facing cities across the world. Variations to each of the four contexts exist, but the framework outlined in this chapter is a useful typology of common transport issues and corresponding policy measures for cities across the world.

Developing cities. Rapidly developing cities are experiencing increasing demand for transport services and rapid growth in private motorization. Developing cities can have relatively low densities and often have inadequate travel infrastructure, especially for NMT modes (e.g., walking and bicycling) and weak public transit services (e.g., unregulated, poor quality bus operators). Combinations of convenience, inexpensive and subsidized fuels, poor public transit services, and increasing distances due to urban sprawl encourage growth in private motorization. As a result, developing cities generally experience increasing roadway congestion, rising travel injuries and travel fatalities, more local air pollution and larger disparities in access to transport, employment and social services.

Sprawling cities. Sprawling cities tend to have low densities and high urban and suburban sprawl. They often have poorly defined urban cores with commercial and business hubs spread intermittently throughout the urban and metropolitan areas. Public transit use and NMT shares tend to be low, while private motorized transport tends to be the primary means of travel. These cities may have difficulty providing efficient and cost-effective public transit services because of long distances between destinations. Local congestion, especially during commuting hours, is high in sprawling cities, and road infrastructure often requires heavy investments and maintenance as a result of extensive, highly travelled networks. Local air pollution and road safety are also common issues of concern.

Congested cities. Heavy roadway traffic, especially during peak travel hours, is common in congested cities. These cities generally have medium to high densities and strong urban cores, although urban sprawl may exist in surrounding metropolitan areas. Congested cities can have extensive transit systems and high public transport modal shares. However, heavy traffic levels, often paired with increasing motorization, can lead to daily gridlock throughout these cities. Numerous causes, including poor or diminishing public transport, fuel subsidies, free or subsidized parking, and high levels of funding for roadway networks, all can contribute to the preference to use private motor vehicles. Zoning policies can also encourage private vehicle use. Local air pollution, road injuries, and travel fatalities can be major issues in these cities.

Multi-modal cities. These cities typically have high densities, strong urban cores, and high public transit and NMT shares. Multi-modal cities generally have strongly interconnected, well-developed travel networks, which facilitate and encourage more efficient travel. Mixed land-use development paired with a high level of public transport services means that travelers generally have good access to energy-efficient modes and a choice of different modes depending on their preferences and needs. Many multi-modal cities have dedicated spaces for more energy-efficient travel modes, such as bus and cycling lanes. A key feature of these cities is also public transport terminals where several modes of public transport can be seamlessly accessed by users. In addition, these cities often have implemented policies that discourage driving, such as limits on parking, road pricing schemes, and car-free zones.

Different Policies for Different Cities

Different policy measures should be applicable to the four different city typologies. Many of the policies are applicable in numerous contexts, although cities should take into account their own specific local transport needs and issues when considering policy targets.

Policies for developing cities. Developing cities often still have a rare opportunity to direct land use and travel growth toward energy-efficient transport systems before urban form and transport network development are strongly established. Target policies include regulations that discourage or penalize sprawling development and land-use initiatives that prioritize dense urban cores. Transport infrastructure development can help to steer growth in travel demand toward more energy-efficient modes while improving access to destinations and travel choice.

At the same time, infrastructure development and land-use policies should be paired with well-coordinated, complementary travel demand management policies to ensure that improvements are accessible, affordable, and attractive (i.e., competitive with private motorization). Policies include formalizing and regulating public transport operations, increasing service quality and frequency on public transport networks, and discouraging private motorized travel (e.g., removal of fuel subsidies and implementing vehicle registration fees). Additional tools to combat growing motorization include policies such as road pricing and eco-driving programs. Improving policies (e.g., fuel-economy and emissions standards enforced through mandatory inspections) should help to increase energy efficiency of motorized transport while mitigating local air pollution.

Sprawling cities. Low densities, urban sprawl, and heavy traffic in sprawling cities require strategic, comprehensive planning and policy actions. Transitioning to a denser urban environment that supports more efficient transport generally requires years of planning and development, especially in cities where urban form is well established. For this reason, medium- and long-term development goals are critical in addressing travel demand. Land-use policies that address denser development, such as density credits and unified regional planning guidelines, can help to discourage continued sprawl and increase urban core development. Long-term zoning strategies, builder incentives, and tax credits for business relocation are examples of policies that encourage urban densification.

In the shorter term, policies that improve existing transport and prioritize shifts away from private motorized travel are important. These policies can include travel demand management programs, such as parking reform and road pricing, as well as tools that focus on improving transport and travel flow (e.g., advanced traffic signal control and buyer incentives for alternative vehicle technologies). At the same time, policies that improve roadway travel can have rebound effects (i.e., increased motorization due to improved travel flow). Short-term system improvements, therefore, should seek to serve or at least complement long-term objectives rather than temporarily relieve existing transport problems. These improvements include supporting travel choice (e.g., park-and-ride stations), addressing shortcomings in existing public transport networks (e.g., redesigning bus routes and frequencies) and building more efficient travel infrastructure, such as BRT and light rail. Additional policies include incentives that encourage shifts away from private vehicles.

Congested cities. Travel demand management policies are useful tools in congested cities to improve and facilitate shifts to more energy-efficient travel while improving existing travel movements. Policies that discourage vehicle ownership (e.g., vehicle quotas and vehicle registration taxes) and private motorized travel (e.g., road pricing and parking fees) can help to reduce or stabilize increasing traffic levels. Improved travel management technologies, such as advanced traffic signalization and real-time travel information, can help to improve mobility and system flow, while incentives (e.g., rideshare incentives) can encourage additional shifts to more efficient travel.

In short term, policies and programs that respond to existing gaps in travel networks (e.g., seamless connections between travel modes) can help improve passenger travels and encourage shifts away from private motorized vehicles. The policy tools are even more effective when paired with travel demand management measures. Medium- to long-term policies that address transport system development (e.g., increased funding streams to develop and improve public transport services) and an improved land-use transport interface (i.e., improved match between travel demand and destination) will encourage longer term shifts to more efficient travel options can encourage greater shifts to more efficient modes and increase efficiency of the entire transport system. These efforts include development of dedicated facilities for energy-efficient modes (e.g., bus and cycling lanes) and investments in vehicle technology improvements for both public and private vehicle fleets.

Travel demand management policies are particularly useful in multi-modal cities to maintain or improve travel shares by more efficient transport modes. Examples of policies used to achieve additional improvements in transport system efficiency include transit incentive programs, car-free zones, parking levies, and road pricing schemes. Cities are increasingly turning to technology to improve urban travel and transport efficiency. This technology includes “real-time” updates of road conditions and transit arrivals, smart phone travel applications, and online journey calculators. Other practical tools, such as geospatial analysis software, can help cities to identify gaps in transport services and infrastructure (e.g., proximity to transit and sidewalk access to bus stops).

Effective policy measures seek to achieve both immediate transport objectives and long-term city goals. These objectives can entail broader goals for the city, including economic growth, social equity, and improved health. For example, the Mayor of London announced a transport vision in 2008, called “Way to Go!”, as part of a broader set of social, economic, and environmental goals for the city. The transport strategy contained six broad targets for transportation, including improving the travel safety of all Londoners, supporting economic development and population growth, improving transport opportunities for all travelers, and reducing transport’s contribution to climate change. Specific transport policies were created to achieve the stated goals.

When considering responses to transport and travel needs, policy makers should identify targets and policy goals that respond to the local context and transport issues. For example, a city with increasing private motorization may set a broad target to improve travel choices and to double the share of trips taken by public transport over the next 10 years. This kind of broad policy objective can help to frame specific policy decisions in response to identified needs, for example, building a BRT network to provide greater travel choice and support increased public transit use.

11.3.1 Public and Private Partnership in Financing Transport Projects

Governments can encourage private investments by implementing regulatory reforms to establish transparency in the rules and regulations governing transport investments and the structure of PPPs. This transparency will help establish (1) competitive procurements with clear rules about the bidding and selection process, (2) full disclosure of conditions before the bidding process to facilitate negotiations, (3) detailed agreements on responsibilities and risks, (4) clear rules on project cancelation and compensation, and (5) pricing regulations to secure revenue while incentivizing new participants. The choice among diversified PPP business models and the extent of private participation should be driven by market efficiency, a proper allocation of risks and a full assessment of costs and benefits for both the public sector and private investors.

PPPs are most effective when they increase the efficiency of transport projects in a regulated, profit-driven structure, and the procurement of private services should optimize outputs compared to costs (i.e., the project should yield the most value while environmental, social, and economic public benefits exceed the costs.

11.3.2 Examples of Project Financing in the Urban Transport Sector

This section briefly presents three real case-based examples on project financing in green urban transport. These projects were co-financed by the GEF, the UNDP, national governments of Russia and China, and private firms in the two countries.

Example 1

In 2009, Russia became the country with the largest vehicle population in Europe, overtaking Germany. Vehicle fuel efficiency marginally improved with the sustained growth of the automotive market. However, due to wide use of less efficient vehicles, including new ones manufactured domestically and imported used ones, vehicle energy intensity in Russia is higher than in all other countries in the EU.

As over 70 % of Russia's population resides in cities, energy consumption in the transportation sector is concentrated in urban areas. With the growth of the automotive market, urban traffic loads are expected to exceed road capacities in many cities, exacerbating urban traffic congestion.

The GEF was leveraging funding for a project to reduce GHG emissions from urban transport systems in medium-sized Russian cities. Approaches of the project included sustainable integrated transport planning, shifting from less efficient and more polluting transportation modes to more efficient and less polluting ones, and demonstration of sustainable low-GHG transport technologies.

The GEF project supported Kazan to prepare its sustainable urban transport (SUT) system in the city where the 2013 Summer Universiade was held. The SUT system developed for the Universiade will also be used for the 2018 FIFA World Cup. The project has enabled the city to gradually reduce the use of private cars and encourage the use of more fuel-efficient cars.

This project directly mitigated approximately four million tonnes of CO_2 equivalent. Increased use of low-emission vehicles and development of SUT projects in medium-sized Russian cities also provide a great potential of scaling-up the project in the country.

Example 2

China's economic growth has sparked an increase in automotive fleets. Vehicle sales in China grew from 2.4 million in 2001 to 5.6 million in 2005, to 7.2 million in 2006 (IPCC 2007), and to 22.0 million in 2013 (CAAM 2014). Globally, GHG emissions from the transport sector are growing rapidly, reaching 6.4 giga tonnes of CO_2eq ($GtCO_2$) in 2006—23 % of the world's energy-related CO_2 emissions (IEA 2008) and 6.7 $GtCO_2$ (7.0 $GtCO_2$eq including non-CO_2 gases) of direct GHG emissions in 2010—23 % of world's energy-related CO_2 emissions (IPCC 2014).

To help encourage the use of lower emission public transportation, the GEF leveraged funding for a project that demonstrated electric buses powered solely by lithium-ion (or Li-ion) batteries at the Beijing Olympics. These buses used fuel cell technology (FC) and a rechargeable lithium-ion battery to power an electric motor and motor controller, rather than a gasoline or diesel engine, resulting in minimal emissions.

The Beijing Municipal Environmental Protection Bureau demonstrated the feasibility of using 50 of these buses (Fig. 11.1) at the Olympics (4 directly financed by the GEF) and conducted an outreach program to encourage the acceleration of the development and deployment of clean vehicle technologies throughout China.

Fig. 11.1 A fuel cell bus used in Beijing in 2008

The outreach program also aimed to raise the awareness of athletes, the media, and the general public about global environmental issues and how individuals can help reduce their negative impact on the environment.

This project directly mitigated 765 tonnes of CO_2. Also, following the GEF project in Beijing, China launched a “10 city, 1,000 buses” initiative to encourage the adoption and development of alternative fuel buses across the country. This initiative called for more than 10 of China’s large cities, including Shanghai, Beijing, Chongqing, Shenzhen, Wuhan, and Zhuzhou, to put 1,000 alternative fuel vehicles on the streets within the next three to four years. In doing so, these cities contributed toward the national goal of having 10 % of China’s domestic vehicles using alternative fuel.

Example 3

An estimated, 1.2 million people attended the Sochi XXII Winter Olympics in February 2014 to watch the world’s best winter athletes compete for gold. To prepare for the Olympics, Sochi was constructing 11 athletic venues divided into two clusters along the coastline and in the mountains. The city was also building a new railway to travel the 48 km distance between the venue clusters and was planning to add other methods of transportation, new power infrastructure, and accommodations.

Between 1992 and 2000, total CO_2 emissions from fossil fuel use in Russia dropped 24.6 % to 1.4 billion tonnes, but rose again to 1.78 billion tonnes in 2007. Russia was the third largest CO_2 emitting country in the world. Emissions from natural gas consumption represent the largest fraction of Russia’s emissions (42 %), followed by oil (39 %) and then coal consumption, whose emissions make up 11 % (Boden et al. 2009).

The new construction and infrastructure improvements taking place in Sochi in preparation for the Olympics presented a substantial opportunity for Russia to reduce its emissions output. With support from the GEF, the Ministry of Natural Resources and Environment of Russia produced a Greening Strategy and Action Plan for the 2014 Olympics. The plan facilitated climate change initiatives early in the planning process to help set up a carbon-neutral event and unleash the potential for greenhouse gas emission reduction during the games.

The project included the development of greening recommendations and action plans for six sectors: green building standards, energy efficiency and power planning, renewable energy technologies, low-carbon transport, carbon offsets, and public awareness and advocacy. The action plans were implemented during the planning phase and during the event to help ensure a carbon-neutral 2014 Winter Olympics and encouraged the future transfer of technologies to other cities throughout Russia. This project mitigated over 700,000 tonnes of CO_2 directly.

11.3.3 Replacement of Energy and Transport with Information Technology

The future of urban public transportation, as well as that of car, will be affected by information technologies. A possibility is to replace the transportation of information and of information-processing workers with transmitting information electronically. In earlier times, almost all communication required transportation, either in the form of a written message or through the travel of a messenger. The ability to move information by telephone began the process of separating the two fields. Although the overall effect was to generate much more movement of information and add to our radius of activity, in many cases, use of telephone made it possible to forego a trip. Communications became an actual substitute for transportation.

Developments in fiber optics, computers, and internet have added new dimensions to communicating that further the possibilities of taking over some of the functions previously performed by transportation. With an increasing percentage of work functions involving information processing, many tasks can be performed wherever there is a computer terminal and a telephone connection. Working from home or in workstations close to home reduces demand for both car travel and public transit services.

11.4 Conclusions and Looking Ahead

Some of our daily activities requiring transportation might be accomplished without traveling or with less traveling. Two possibilities on the demand side offer the greatest promise. The first is the growing ability to move information to people instead of moving people to information. The second is the design and redesign of city and suburb to substitute convenient location of urban activities for the travel that inconvenient land-use arrangements have imposed on urban residents.

With improved communications and more convenient communities, transportation would stand a better chance of operating more effectively. Trains, taxis, cars, bicycles, and walking sidewalks, viewed as a total transportation resource, could be integrated system to further mobility and enhance urban environments.

In the dispersed regional city of the future, public transportation will be needed to carry out five essential functions to

1. guarantee citywide mobility for the growing number of people who are non-drivers by choice or necessity,
2. supply the exclusive means of travel in high-density areas where private cars are prohibited,
3. complement the services rendered by the automobile on trips,

4. provide local extensions of the intercity and global public transportation networks, and
5. help to create a more satisfying, manageable, and pollution-free urban environment that maximizes the ability to move while minimizing the necessity for movement.

Urban transportation as a seamless integrated system of shared transportation options powered by energy-efficient system is emerging. Such a system would replace disconnected modes of transport, such as cars, bikes, buses, and trains, with an integrated system that incorporates all of them. Citizens are urged to consider mobility services as opposed to stand-alone vehicles to encourage a more sustainable approach to reaching their destinations. Railways are the central system that connects citizens to the different modes of mobility. For example, a professional on his/her way to work may ride a fee bicycle to the train station. Next, he/she can take the train to the stop nearest his/her office. From the station, he/she will have the option of driving an electric car parked nearby, or walking the last mile to his/her office. The carbon footprint of his/her entire mobility chain could approach zero, and he/she would have used shared transportation modes throughout, with economies of scale providing cheaper as well as more efficient transportation. Creating a seamless mobility chain that involves multiple providers (car manufacturers, public transport providers, charging infrastructure providers, energy suppliers, train operators, parking space owners, etc.) requires implementation of an integrated infrastructure in which different elements can seamlessly communicate. The information layer of such an infrastructure is a key component. A smart phone application can allow users to determine a route (and associated transportation modes) based on real-time updates about train and bus schedules, traffic conditions, availability of shared bicycles, charging stations of cars nearby, weather conditions, and fares.

References

Boden TA, Marland G, Andres RJ (2009) Global, regional, and national fossil-fuel CO_2 emissions. Oak Ridge Carbon Dioxide Info Anal Center Oak Ridge Nat Lab US Dept Energy. http://cdiac.ornl.gov/trends/emis/tre_ind.html; http://cdiac.ornl.gov/trends/emis/tre_rus.html

CAAM—China Automobile Association of Manufacturers (2014) The sales and production set another record and enjoyed a dramatic growth. http://www.caam.org.cn/AutomotivesStatistics/20140113/1605112294.html Accessed 18 May 2014

IEA—International Energy Agency (2008) World energy outlook 2008. IEA, Paris

IEA—International Energy Agency (2013) A tale of renewed cities: a policy guide on how to transform cities by improving energy efficiency in urban transport systems. International Energy Agency, 9 rue de la Fédération, 75739 Paris Cedex 15, France. www.iea.org

IPCC—Intergovernmental Panel on Climate Change (2007) IPCC fourth assessment report: climate change 2007 (AR4). http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml. Accessed 29 Nov 2011

IPCC—Intergovernmental Panel on Climate Change (2014) Climate change 2014: mitigation of climate change. IPCC Working Group III contribution to AR5. http://mitigation2014.org/

Chapter 12
Case Studies

This chapter consists of two case studies. The first one is on energy efficiency improvement in China's electrical motors, and the second one demonstrates efficiency, investment, system operation in the sector of China's industrial boiler.

12.1 Case Study Paper 1: Raising China's Motor Efficiency

12.1.1 Abstract

Electric motors are widely used as a power source for mechanical equipment in all fields of national economic development, and power consumption by motors is huge. Statistics shows that the capacity of China's total installed electric motors reached more than 2.78 TW in 2013. Electricity consumption by electrical motors in China was 3,092 TWh in 2013 and is projected to grow to more than 3,600 TWh in 2020, accounting for about 64 % of total electricity consumption in the country or 88 % of total electricity consumption in the Chinese industry (China Electric Motor 2014). Of all these figures, over 75 % is attributed to inefficient medium and large induction motor systems (with a capacity of 10 kW/unit). Large induction motors consumed 2,271 TWh electricity in 2013 in China. Thus, improving energy efficiency in large electrical motor systems provides a great potential for energy savings and environment conservation. A number of energy technologies—including intelligent motor controllers, which are computerized devices to minimize energy inputs according to the drive loads of the motor systems—have been developed to exploit this potential. The objective of this case study was to identify the cost-effectiveness of improving energy efficiency of China's medium and large induction motor systems by using intelligent motor controllers. On-site interviews with technology investors and users have been undertaken. Financial and economic analyses have been undertaken to justify cost-effectiveness. Two analytic scenarios have been designed to assess the impacts of energy efficiency policy on energy

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_12

savings. CO_2 emission mitigations due to the use of advanced technology have been estimated. Four barriers to using new and wider technologies have also been identified. This cases study concludes that (1) using intelligent motor controllers in China is financially viable within a payback period of less than two years; and (2) CO_2 reduction could be over 596 million tonnes from 2014 to 2020, approximately 6 % of total CO_2 emission China in 2013 (authors' calculation).

12.1.2 Introduction

Electrical motors are the major electricity consumption equipment in China. In 2013, about 3,092 TWh or 624 of total final generated electricity was consumed by motors. Large motors (with unit capacity more than 10 kW) used about 2,125 TWh or 44 % of the total power supply of the country (China Electric Motor 2014).

The energy efficiency standards of the Chinese electrical motors in general are 2–8 % lower than the EU standards. Most motors in the Chinese market follow the design parameters of the International Electrotechnical Commission (IEC). The Chinese Minimum Energy Performance Standards (MEPS) for motors that were publicized in 2002 are equal to the minimum limit of the EU EFF2. The efficiency difference between EU EFF1 and EU EFF2 is roughly between 2 % (95–93 %) for large motors (>75 kW) and 8 % (84–76 %) for small motors (about 1 kW). In 2010, the Chinese government raised the national motor standards up to IE3 and ready to take IE4 standards (Zhang 2011). In addition, most of the high-efficient motors (with IE3 standards) made in China have been exported. Low standards of efficiency and exporting high-efficient motors caused low-efficient electric motor population in China.

Large motors and motor systems are of major share of electrical motor population in China. An on-site random survey on the distribution of the motor size in China was undertaken by one of the authors in 2013 for 85,069 motors and motor systems (Danish Energy Management 2005). Their results showed that 73 % of the surveyed motors and motor systems in China have capacity between 10 and 200 kW/unit, and about 25 % are of 10 kW/unit. The average capacities for the whole motor population and for the large motors are 41 and 55 kW/unit (Fig. 12.1).

The average motor efficiency in China is approximately 90 at 100 % load (MIIT 2014). If China could increase the average efficiency from 90 % to a technically achievable 96 %, China could save at least 129 TWh in 2013, which is equivalent to 155 % of total electricity production of the Three Gorges Power Plant of China in 2013. Actually, most of motors are far below 100 % load while they are in operation. An on-site survey in ten Chinese industrial premises by the author in early 2014 revealed that over 70 % of motors are operating under 70 % of their rated load capacity. Idling, cyclic, lightly loaded, or oversized motors consume more power than required even when they are not working. These motors are wasting energy, generating excessive utility costs, and unnecessary motor wear. Thus, there is a huge potential of energy and cost savings in motor systems in China.

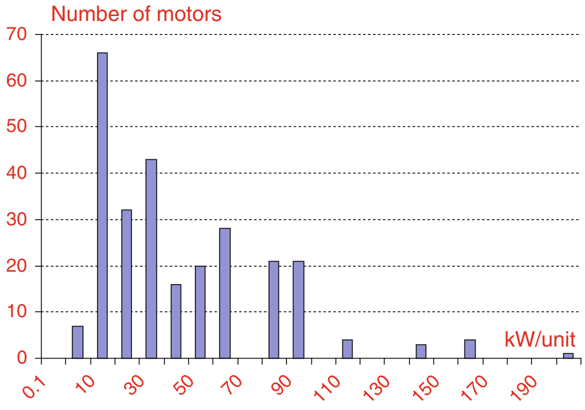


Fig. 12.1 Motor capacity distributions. *Source* Authors' data and design

A number of technologies and measures have been recently developed to improve energy efficiency for large motors and motor systems. These include intelligent motor controllers (IMCs)—computerized devices that optimize motor drive systems while maintaining constant motor speed. In France, Mexico, the UK, and the USA, IMCs have been practically used to raise energy efficiency for large motor systems.

The objective of this case study is to identify the effectiveness of using intelligent motor controllers to save electricity in motors and motor systems in China. The authors interviewed technology investors and users and undertook program financial and economic assessments to assess cost-effectiveness of IMC technologies. Two analytic scenarios (business as usual or BAU and energy efficiency policy or energy efficiency scenarios) were designed to assess the impacts of energy efficiency policy on electricity savings and CO_2 mitigations. The case study also identified a number of barriers to using IMC technologies in China.

This case study consists of five sections. After the introductory section, the authors present the methodology used in the study. In Sect. 12.1.3, the authors review the state of the art of intelligent motor control systems and the most recent applications of this technology in France and Mexico. Section 12.1.4, which is the core of this paper, demonstrates our cost-effectiveness analysis procedures and results. Section 12.1.5 shows a study in China Finally, conclusion and policy recommendations are presented in Sect. 12.1.6.

12.1.3 Methodology and Approaches in This Case Study

A top-down analytical methodology is used to perform the case study. It starts from the national macro-level to project final electricity consumption in China and down to micro-project financial analysis. The methodology framework is presented in Fig. 12.2. The methodology is designed according to the availability of the data to

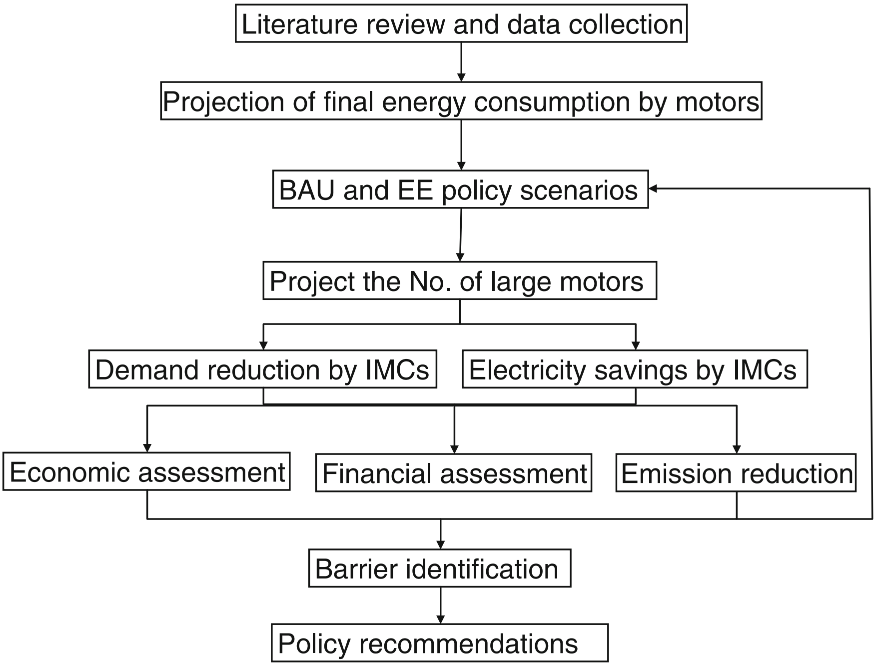


Fig. 12.2 Methodological framework. *Source* Authors' data and design

accomplish various analyses under the business as usual and energy efficiency scenarios. Our quantitative analysis methodology covers projection of total final electricity consumption in China by large motors, design of two scenarios, calculation of energy savings and power demand avoidance by using IMCs, pollution reductions, and cost-benefit estimations from the perspectives of the national government and the individual investors of the IMC devices.

Literature review, interviews, and experiments of an IMC device with an induction motor have been undertaken for the purpose of data collection. The authors also undertook a telephone interview with an investor in Mexico who has invested over 100 IMCs in a Mexican company and another phone interview with an IMC technology providing firm in the USA to verify the collected data.

A simple time series econometric model is used to project final electricity consumption and the share of electricity consumption by large motors. Our regression exercise showed that the electricity consumption by large motors has been growing exponentially with the following function, and the authors assumed the consumption will follow this trend until 2020:

$$E = 106 + 92\,\mathrm{e}^{0.0794\times(t-1980)}$$

where

E (in TWh) is electricity consumption by large motors in year t

e is the base of natural logarithm (=2.71828)

t is any year between 2007 and 2020

Whiling calculating the number of electrical motors, the authors used the following model:

$$N = \frac{\mathrm{Dc}}{\mathrm{Cf} \times U \times S}$$

where

N (in thousand) is the total number of large motor and motor systems in China in year t

Dc in gigawatt (GW) is the annual demand cut by using IMCs in year t

Cf (in %) is the coincidence factor of motor running. The authors set it as 36.5 % in the model, calculated according to our assumption: Motors are running 3,200 h a year on average

U (in kW/unit) is the average unit capacity of the induction motors in China. The authors used 55 kW, the survey result of the Danish Energy Management (2005)

S (in %) is the share of savings by using IMCs. In this analysis, the authors used 20 %, the survey result of the IMC investors and users in France and Mexico (see the following section for more details)

The BAU and energy efficiency scenarios are designed on the basis of our desk literature review, phone interview with the IMC providers, and a number of Chinese policy makers in the National Development and Reform Commission and professionals in the State Power Economic Research Centre. The authors also performed several rounds of try-and-error calculations to estimate the impacts of different policy scenarios before finalizing the energy efficiency policy scenario in the study. Under the two scenarios, simple MS Excel spreadsheet models are developed to perform the calculations of electricity savings, demand reduction, economic and financial assessment, and GHG mitigation.

While undertaking the economic cost estimation, the authors only took into account the costs of the device production, but not the costs of policy development and information campaigns because of the difficulties to quantify these costs. In the financial analysis, from the perspective of the owners of IMCs, the analysis was based on one piece of the device. This method will simplify the analysis and will not harm the results.

The annual cut of power generation is calculated from the annual cut of demand taking into account 15 % of the power transmission and distribution (T&D) losses. While calculating the avoidable investment in power generation, the authors assumed US$1,074/kW as capital cost with a deduction of government tax (31 %)

but without adding the costs of investment in power T&D networks. The number of IMCs is derived from the following assumptions: (1) 55 kW/unit for motor system capacity; (2) 37 % for motor operation coincidence factor (3,200 h/year divided by 8,760 h/year); and (3) 20 % of power savings by IMCs.

In the following, the authors further present our literature review results, apply the collection data into the above-mentioned methodology, perform analysis, and present our results.

12.1.4 Intelligent Motor Controllers

An intelligent motor controller, a computerized device, saves energy by measuring the workload on the motor by comparing the difference in voltage and current waveforms at the motor. This information is then used to raise power factor of the motor and reduce the current and voltage to match the workload as required by the motor, while maintaining constant speed. This transaction takes place 120 times per second which prevents the motor from stalling under any and all changes to motor load conditions. Figure 12.3 illustrates an IMC that compensates reactive power and improves power factor. Because the IMC can adjust power consumption proportional to motor loading conditions without altering motor revolutions per minute (rpm), it reduces φ or raises cosφ of the power system, cuts excess current which is normally dissipated as heat through the motor is eliminated. As a result, the motor runs cooler, quieter and with less vibration, saving energy, cutting down operation costs, and extending motor life. Nowadays, an IMC can be integrated into induction motor during the manufacturing of a new motor. It can also be made individually and installed to existing or old motors externally.

Practically, with an IMC, an induction motor can save up to 20 % of energy. Figure 12.4 shows a real on-site measurement of power consumption by a motor system in France under two conditions: with and without an IMC. With the IMC,

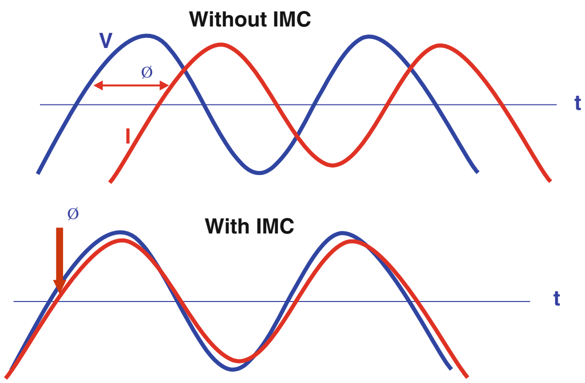


Fig. 12.3 IMC improves system power factor. *Source* Authors' data and design

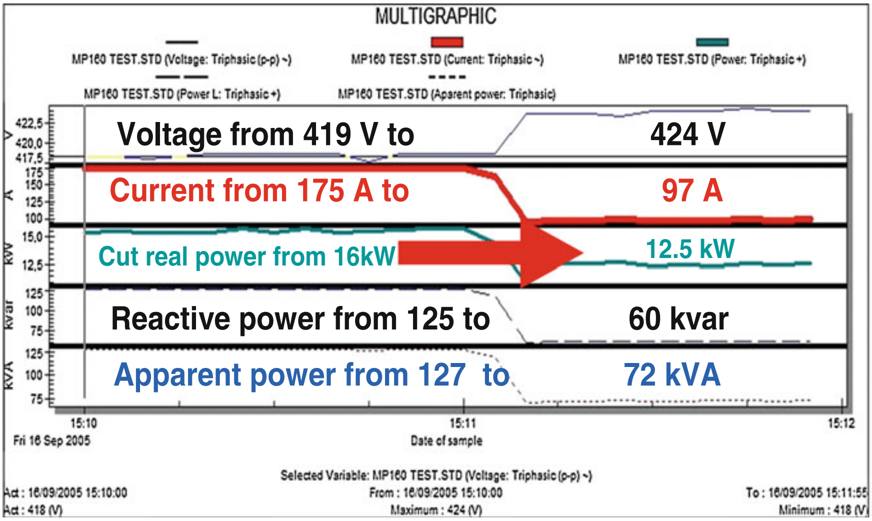


Fig. 12.4 IMC saves energy and improves system power factor. *Source* Authors designed from a survey data in France in 2006

the induction motor raises system voltage rather than reduces it. It cuts more than a half of reactive power. The IMC helped cut down 3.5 kW of power for a 16 kW motor system, saving 22 % of power consumption.

According to another on-site survey study in Mexico, investing IMCs is financially viable. Over the past few years, Intelsteer Co Ltd, an international ESCO, has invested millions of dollars in IMC business in Mexico and Singapore. In Mexico, the ESCO has installed over 100 IMC units for a single industrial customer. The ESCO has recently undertaken a post-investment evaluation. Table 12.1 highlights the results of the study. The average capital cost of the 102 IMC units was about US$3,740/unit. The investment was recouped in 1.5 years. An IMC saves real power consumption by about 20 % or electricity consumption by 1.27 MWh/unit/year. After installing an IMC, the users will save electricity bills of US$2,400/unit/year. In addition, each IMC helps reduce 880 kg of CO_2 emissions annually.

Table 12.1 Survey results from Mexico

Indicator	Values
IMC investment (US$/102 units)	381,000
Real power savings	19 %
Electricity cost reduction (US$/year)	243,840
Payback period (year)	1.5
CO_2 reduction (ton/year)	90

Source Intelsteer Co. Ltd. (2006)

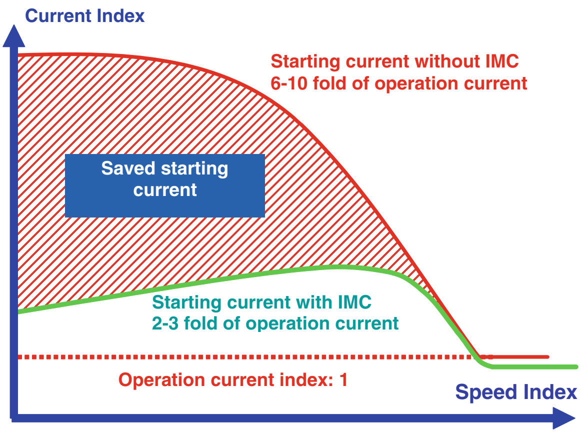


Fig. 12.5 IMC saves starting current. *Source* Authors' data and design

An IMC also cuts down the starting current and extends the lifetime of motors. Full voltage hard starts can damage motors as well as equipment. An IMC can control the inrush of current, prevents unnecessary excess torque, and reduces power grid disturbances. The soft-start circuit in the motor controller senses the motor load and the power to the motor. It then applies only the exact power required to start the motor without reducing the necessary starting torque or rpm. Actual kW demand is reduced and the power factor is improved. According to a test by Intelsteer Co Ltd in 2006, an IMC reduces the peak current by over 50 % at the staring period of a motor operation. Figure 12.5 shows the reduction of starting current of the motors by using the IMC.

12.1.5 Study in China

12.1.5.1 Projection of Power Consumption by Large Induction Motors by 2020

In this study, the authors projected the total electricity consumption and the share by large induction motors in the Chinese industrial and commercial sectors. On the basis of the historical power consumption data, the authors use a time series econometric model taking into account the growth of China's per capita GDP (quadrupling between 2000 and 2020). Our projected results show that large induction motors will consume about 3,110 TWh or 47 % of the total electricity use in China (Fig. 12.6).

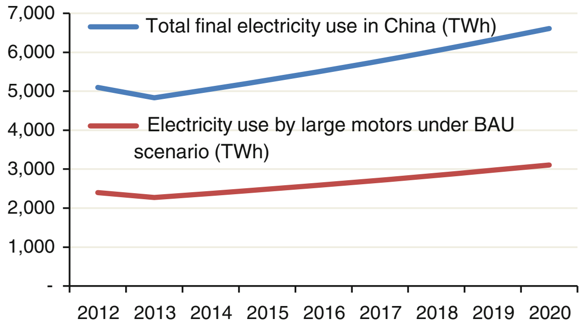


Fig. 12.6 Total electricity consumption and shares by large induction motors. *Source* Authors' data and design

12.1.5.2 Assumptions of Business as Usual and Energy Efficiency Scenarios

In this case study, the authors made some assumptions and two scenarios: business as usual and energy efficiency policy scenarios. The assumptions that are appropriate for all the two scenarios are as follows:

1. Weighted average capacity of medium and large motors: 55 kW/unit.
2. Motor's average running time: 3,200 h/year/unit (16 h per day and 200 days a year).
3. Between 2013 and 2020, electricity consumption by large motors and motor systems will increase as projected in Fig. 12.6.
4. Electricity price is US$0.10/kWh (in 2010 price) in 2012. This price will gradually grow up to US$0.15/kWh (in 2010 price) in 2020.
5. Discount rates are 12 % for national economic assessment and 20 % for financial investment assessment.

In the BAU scenario, the authors assume that the government, investors, and the stakeholders of the induction motors will not significantly use IMC technologies. Specifically, the BAU scenario contains the following features:

1. The average energy efficiency of induction motors will be 60 % and the load of the motors will be 60 %.
2. By 2020, only 0.1 % motors will be installed with intelligent motor controllers due to natural penetration of the technology in China.

In the energy efficiency policy scenario, the government, private investors, motor manufacturers, and consumers will take actions to use IMCs. Specifically, the following key features describe the energy efficiency scenario:

1. From 2014, IMC technologies will penetrate to the large induction motors in the market at 1 % of the large motors at the first years and gradually increase and accumulatively approach to 15 % of the total large motor population by 2020.
2. Each IMC device will save 20 % of power for an induction motor system.

3. Total marginal cost of an IMC device is US$2,925 (2010 constant price), including US$1,950/unit capital cost and US$975/unit of installation cost.
4. Annual marginal O&M cost of the device is 5 % of the capital investment and installation costs at the second year of the installation. This cost will grow at the rate of 3 % per year up to 2020.
5. The national government will make new standards for induction motors to promote IMC technologies.

12.1.5.3 Analysis Results

Electricity savings under the energy efficiency scenario: The authors calculated electricity savings between the BAU scenario and the energy efficiency scenario, and Table 12.2 shows the results. Under the BAU scenario, total electricity consumption in China will grow exponentially from 4,831 TWh in 2013 to 6,612 TWh in 2020. From 2014 to 2020, if 20 % of large electrical motors in the Chinese market are equipped with IMCs, China will approximately save 116 TWh of electricity per year, which is more than that generated from the Three Gorges Power Plant of China each year.

Table 12.2 Power savings and pollution reductions by IMCs

Indicators	2013	2014	2015	2016	2017	2018	2019	2020
Total final electricity use in China (TWh)	4,831	5,053	5,285	5,527	5,780	6,045	6,322	6,612
Electricity use by large motors under BAU scenario (TWh)	2,271	2,375	2,484	2,598	2,717	2,841	2,972	3,108
Electricity use by large motors under energy efficiency scenario (TWh)	2,039	2,132	2,230	2,332	2,439	2,551	2,667	2,789
Energy savings by IMCs (TWh)	85	89	93	97	102	106	111	116
Accumulated capacity cut by IMCs (GW)	18.3	19.1	19.9	20.9	21.8	22.8	23.8	25.0
GHG mitigations (CO_2 eq million ton)	70	74	77	82	85	89	93	96
SO_2 mitigation (thousand ton)	569	596	623	652	682	713	745	780
No_X mitigation (thousand ton)	220	231	242	252	264	277	289	302

12.1.5.4 Environment Benefits

The authors estimated the environment benefits achieved by installing IMCs to large induction motors in China. The mix of China's power generation was expected to remain unchanged for a long time.

According to the Energy Research Institute of the National Development and Reform Commission, China will mainly use critical and supercritical technologies in power generation in the next 10 years. The emission factors for such technologies are as follows: 833 g CO_2/kWh, 6.7 g SO_2/kWh, and 2.6 g NO_x/kWh. For oil-fired power plants, the authors assume the emission factors are half those from the above-mentioned coal-fired plants. For natural gas-fired plants, the emission factors are 174.2 g CO_2/kWh, none for SO_2, and 0.3 g NO_x/kWh. Then, between 2014 and 2020, IMCs will bring about a total of 596 million tonnes of CO_2 reduction, 4.79 million tonnes of SO_2, and 1.86 million tonnes of NO_x in China (Table 12.2).

12.1.5.5 Cost-Benefit Assessments

The authors also briefly undertook cost-benefit assessments from both the national capital investment perspective and the micro-IMC investor's financing perspective. While doing the financial assessment, the authors performed the calculation on the basis of one unit of IMC investment. This simplified our analysis but did not harm the results for decision making.

12.1.5.6 National Investment Assessment

On the basis of the avoidable power demand data in Table 12.2, the authors estimated the avoidable capital investments in power plants in China. The annual avoidable power generation is calculated from the annual avoidable demand taking into account 15 % of the power T&D losses. IMCs will help avoid power generation capacity from by 18.3 GW in 2013 to 25.0 GW in 2020, with a total reduction of 6 GW in the period of 2014–2020. The savings of the capital investment in the power generation capacity will be significantly more than the national capital expenditure in IMC technologies. This results in positive cash flows in all years from 2014 up to 2020. The net present value of the national program of IMCs under the current scenario is over US$241 million (Table 12.3).

The IMC technologies will enforce China's energy security by avoiding billions of dollars in investing new power plants. On October 24, 2012, the State Council of China issued a white paper on energy policy. The policy paper stated that China will raise the proportion of clean, low-carbon fossil energy and non-fossil energy in the energy mix and promote efficient and clean utilization of coal. It aims to increase the shares of non-fossil fuels in primary energy consumption. It reads

Table 12.3 Savings of national capital investment

Indicators	2014	2015	2016	2017	2018	2019	2020
Annual cut of power demand (GW)	0.9	0.8	1.0	0.9	1.0	1.0	1.2
Annual cut of power generation (GW)	1.0	0.9	1.1	1.1	1.1	1.2	1.4
Avoidable investment in power generation (million US$)	342	307	390	357	382	377	448
Units of IMC investment (000)	217	195	248	227	243	240	285
Capital investment in IMCs (million US$)	−292	−263	−334	−305	−327	−322	−398
Investment cash flow (million US$)	49	45	56	52	55	55	65
NPV at discount rate of 12 % (million US$)	241						

"China will invest more in nuclear power technological innovations, promote application of advanced technology, improve the equipment level, and attach great importance to personnel training. China's installed capacity of nuclear power is expected to reach 40 GWe by 2015." By 2020, the country's total nuclear generating capacity will reach approximately 70 GW (World Nuclear Association 2012). On average, the capacity of each of the new nuclear power plants will be about 1 GW (500 MW/unit × 2 units). The application of IMCs in China under our energy efficiency scenario will avoid or postpone the installation of one or one and a half large nuclear power plants each year from 2013 to 2020. According to the IEA (2005), overnight construction capital cost for nuclear power plant arranged from US$1,074/kW in Korea to US$2,510/kW in Japan. This figure in China in the 1990s was between US$1,330/kW and US$2,200/kW. In this study, the authors use the data of World Nuclear Association (2012): China's overnight construction capital cost for nuclear power capacity at constant price of US$1,875/kWe from 2014 to 2020. Then, the total avoidable capital investment costs for the country will reach US$14.5 billion!

12.1.5.7 Financial Assessment

A financial assessment is carried out on the basis of one piece of IMC device. The major initial cost of the project (US$2,925/unit) is the sum of the initial equipment investment cost (US$1,950/unit) and installation costs (50 % of equipment investment cost). The authors made the following assumptions in the analysis:

1. Electricity price was average between US$0.075 and US$0.107 in China in 2012 and it will double between 2013 and 2020;
2. The IMC machine will run 100 days per year for 7 years of lifetime; and
3. At the first year of IMC installation, the machine will work 50 days.

Table 12.4 Financial analysis results

	IMC investment and operation costs (US$/unit)	Electricity price (US$/kWh)	Savings (kWh/day)	Savings (US$/unit/year)	Cash flow (US$/unit)
2014	2,925	0.091	176	801	−2,124
2015	170	0.100	176	1,768	1,598
2016	175	0.111	176	1,952	1,777
2017	180	0.122	176	2,156	1,976
2018	185	0.135	176	2,380	2,195
2019	191	0.149	176	2,628	2,437
2020	197	0.165	176	2,901	2,704
2021	203	0.182	176	3,203	3,000
NPV					4,472

Here are the analysis results:

1. The payback period of the investments is less than two years;
2. The NPV under the discount rate of 20 % is approximately US$4,472 if the customer invests US$2,925 for one piece of IMC with a 55 kW motor system. Consequently, the investment is financially viable. See Table 12.4.

12.1.5.8 Barriers to Investing in IMCs

There are several barriers to investments in IMCs in China, although investing in IMCs is economically and financially viable. Our telephone interviews with a number of investors and Chinese industrial stakeholders revealed the following major barriers:

1. The purchasers of motors are generally not end users. Motor users receive motors embedded in equipment or machines. As a result, savings of energy cost do not benefit buyers of equipment or machines, which creates a split incentive similar to the landlord–tenant dilemma in house renting.
2. Not many industrial stakeholders are aware of the IMC technologies. When compared with other energy-efficient technologies such as CFLs and/or variable speed drive motor systems, IMCs are relatively new to users.
3. Initial capital investment is high. When compared to the capital costs of other energy-efficient devices or even electrical motors, the IMC investment is high. Users are usually hesitated to pay high front costs for energy-efficient equipment.
4. There is a lack of standards for high-energy-efficient motors. As indicated in the literature review, the Chinese energy efficiency standards for motors are generally lower than that of the EU. Poor energy efficiency standards do not provide motor users with incentives to raise energy efficiency for induction motors.

12.1.5.9 Policy Recommendations

To achieve the electricity saving targets in motors in 2020, the following policy measures are recommended to the Chinese government:

1. Higher energy efficiency standards and codes for large induction motors should be developed and implemented. For large motors that are newly produced and sold, a built-in IMC device must be equipped. For the existing large ones, external IMCs should be installed step by step by 2020.
2. National and local governments should widely use public media to promote IMC technologies as they do for CFLs and other energy-efficient technologies.
3. Develop new financial mechanisms to overcome the barrier of high costs of front investments in the IMC technology. One example may include good collaboration among investment banks, investors or ESCOs, power utility, and motor users. For example, a commercial bank provides soft loans to the investors or ESCOs who are purchasing the IMC technologies and installing them for the motor users. The motor users will keep paying the same amounts of electricity bills before and after the IMCs are installed in a period of time when the IMCs are in operation. Power utilities will use part of the users' payment to payback the technology investors and the bank.

12.1.6 Conclusions

The use of IMC technology in China offers large potential for the country to implement energy efficiency in a cost-effective way. Over 44 % of electrical power is consumed by large induction motors in China. If 20 % of the induction motor population is equipped with IMC technologies, from 2014 to 2020, China will be able to cut approximately 6 GW of power demand, save 714 TWh of electricity, and mitigate 596 million tonnes of CO_2, 4.8 million tonnes of SO_2, and 1.9 million tonnes of NO_x in China.

Installing and operating IMCs in China are both financially and economically viable. Even under the most conservative scenario, the economic benefits which do not account environment benefit will be greatly larger than the marginal costs. The results of the financial analysis also show that the payback period for investors in IMCs will be less than two years. The net present value of investing one piece of IMC is over US$4,472.

There are a number of barriers to deploying the IMC technologies in China. The government and industrial stakeholders need to work together to promote IMCs in order to achieve the electricity savings and GHG mitigation targets. The priority for the Chinese government policy makers is to update the standards and codes for China's motor and motor systems.

12.2 Case Study Paper 2: Investing in Boiler Steam Systems

12.2.1 Abstract

Energy efficiency in industrial boiler steam systems can be very low due to old technologies, improper design, and non-optimal operation of the steam systems. Solutions include efficiency assessments and investments in steam system optimizations, and education and training for operators of the systems. This case study presents the results of the assessment of boiler steam systems in China and Vietnam. A preliminary assessment is also presented to show energy efficiency potential in industrial boilers and steam systems in Russia. Methodologies and approaches were designed specifically for each country, and data were collected from various sources. This case study concludes that investing in energy efficiency in industrial boiler steam system in these three countries will be cost-effective.

12.2.2 Introduction

The International Energy Agency or IEA (2010) estimated that approximately a third of the world's energy consumption and over 35 % of CO_2, emissions are attributable to manufacturing industries. Industry's use of energy has grown by 71 % between 1971 and 2014, albeit with rapidly growing energy demand in developing countries and stagnating energy demand in OECD countries. Industrial boilers account for a major portion of the energy consumption in the manufacturing industries. On a global basis, the IEA (2007) estimated that the if energy efficiency of boiler steam systems can be improved by at least 10 % (more if steam lines are uninsulated), the global final energy consumption will be reduced by approximately 14 exajoules or 334 million tonnes of oil equivalent (mtoe) in 2008.[1]

Industrial boilers and their steam systems offer a great opportunity for energy savings, a potential remained largely unrealized worldwide. At present, most markets and policy makers tend to focus on individual boiler system components with an improvement potential. The IEA (2007) documented general energy efficiency improvement potentials and measures, average costs to use these measures, and statistic uses of these measures by OECD and non-OECD countries for components of boiler systems (Table 12.5). The IEA's experience with well-managed industrial facilities in OECD countries indicates that there is an energy efficiency improvement opportunity on the order of 10 %.

As one of the good examples in the OECD countries, the US government had a policy initiative in this area. A more recent series of three-day steam and process heating assessments conducted in 2006 at 200 industrial facilities by the United States Department of Energy (US DOE) through their Save Energy Now initiative identified

[1] 474 exajoules × 10 × 30 % = 14 exajoules.

Table 12.5 Energy efficiency improvement potentials and uses in steam systems

	Typical savings (%)	Typical investment (US$/Gj/steam/year)	Use in OECD countries (%)	Use in non-OECD countries (%)
Steam traps	5	1	50	25
Insulation pipelines	5	1	75	25
Feed water economizers	5	10	75	50
Reduced excess air	2	5	100	50
Heat transfer	–	–	75	50
Return condensate	10	10	75	50
Improved blowdown	2–5	20	25	10
Vapor recompression	0–20	30	10	0
Flash condensate	0–10	10	50	25
Vent condenser	1–5	40	25	10
Minimize short cycling	0–5	20	75	50
Insulate values and fittings	1–3	5	50	25

Source IEA (2007)

a total of US$485 million in annual energy savings and 1.31 million toe of annual natural gas savings, which, if implemented, would cut CO_2 emissions by 3.3 million tons. Six months after their assessments, 71 plants had reported almost US$140 million worth of energy saving recommendations completed, underway, or planned.[2] Under this initiative, energy saving potentials at individual components in industrial boiler systems have been well achieved in many industrial facilities in the USA. The following words in italic summarize a public–private partnership between the US DOE and J.R. Simplot Company to reduce energy consumption in a steam system.

In 2006, the J.R. Simplot company's Don Plant in Pocatello, Idaho, received an assessment of the U.S. Department of Energy (DOE) entitled "Save Energy Now". The main objectives of the assessment were to help the plant operate more efficiently by identifying ways to reduce energy use in its steam system. Working with the facility's maintenance engineers, DOE Energy Expert Bill Moir of Steam Engineering Inc. utilized DOE's Steam System Assessment Tool (SSAT) software to identify multiple energy savings opportunities in the plant's steam system. By capitalizing on several of these opportunities, the Plant personnel were able to improve steam system efficiency and reduce energy consumption. The Plant

[2] U.S. DOE, http://www1.eere.energy.gov/industry/saveenergynow/.

began implementing some of the recommendations as soon as the assessment was completed. They optimized boiler operation to reduce steam venting, improved condensate recovery, repaired steam traps, and fixed steam leaks. As a result, the plant realized total annual cost savings of US$335,000. With project costs of approximately US$180,000, the plant achieved a simple payback of approximately 6.5 months. This investment resulted in saving 1,888 tonnes of oil equivalent (toe), and mitigating 6,797 tonnes of CO_2 per annum (U.S. DOE 2008).

Energy equipment manufacturers worldwide have steadily improved the performance of individual system components. For example, boilers with about 94 % efficiency have already been developed and used in the USA (U.S. EPA 2008). To further increase boiler efficiency by an additional percentage, scientists and researchers are working hard to invent new materials and new technologies. But, even when new technologies emerge at all component levels, their significant energy efficiency advantages can be negated by a poorly configured or operated steam system.

While the energy efficiency of individual boilers can be quite high, when viewed as an entire system, their overall efficiency is low in all countries, particularly very low in developing countries. Energy saving potential in a boiler steam system includes the matches of fuel and air inputs for the boilers, optimizations of boiler operations and steam transmission, and waste heat reuse and recycle. Wisconsin Focus on Energy (2011) shows that a typical industrial facility in Wisconsin of the USA can cut 20 % of its fuel costs through implementation of the steam system best practices. These practices include the following: (1) maintain steam traps; (2) reduce system leaks; (3) add insulation to reduce heat loss; (4) tune up boilers regularly; (5) add boiler stack economizers; (6) maximize condensate return; (7) automate blowdown and recover heat from the blowdown stream; (8) recover flash steam heat; and (9) install automatic burner controls. The above practices do not include steam system optimization. If this factor is taken into account, more energy saving potential will be achieved in the steam system.

Box 1: In 2006, the J.R. Simplot Company's Don Plant in Pocatello, Idaho, received an assessment of the US Department of Energy (DOE) entitled "Save Energy Now." The main objectives of the assessment were to help the plant operate more efficiently by identifying ways to reduce energy use in its steam system. Working with the facility's maintenance engineers, DOE Energy Expert Bill Moir of Steam Engineering Inc., utilized DOE's Steam System Assessment Tool (SSAT) software to identify multiple energy saving opportunities in the plant's steam system. By capitalizing on several of these opportunities, the plant personnel were able to improve steam system efficiency and reduce energy consumption. The plant began implementing some of the recommendations as soon as the assessment was completed. They optimized boiler operation to reduce steam venting, improved condensate recovery, repaired steam traps, and fixed steam leaks. As a result, the plant realized total annual cost savings of US$335,000. With project costs of

approximately US$180,000, the plant achieved a simple payback of approximately 6.5 months. This investment resulted in saving 1,888 tons of oil equivalent (toe) and mitigating 6,797 tons of CO_2 per annum (U.S. DOE 2008).

Artificial neural network (ANN) is one of the ways in steam system optimization. ANN is a network application specially designed for steam boilers and steam systems to maintain performance in normal and safe operation conditions. Kalogirou (2000) has presented a brief review of the applications of an ANN in energy systems. Kesgin and Heperkan (2005) applied software programming techniques to simulate the thermodynamic systems. Many other scientists, professors, and engineers, including Chein et al. (1958), Kwan and Anderson (1970), Usoro (1977), Tysso (1981), Adam and Marchetti (1999), Astrom and Bell (2000), and Liu et al. (2001), presented physical modeling of boilers and showed that physical modeling was difficult and complicated. Irwin et al. (1995), De et al. (2007), and Smrekar et al. (2009) reported their work on modeling of conventional coal-fired boilers using ANN. However, none of the above-mentioned authors used real plant data collected on-site of a boiler steam system.

In this case study, most of the data used for analysis were collected on-site in industrial facilities. The data showed that incomplete combustion of oil and coal in boilers was common in Vietnam because designed fuels and actually used fuels did not match most of the time and boiler steam systems were not well maintained. Some boilers' operations were not necessary, since these boilers were producing hot water with low temperature that could be substituted by reusing waste steam from other boilers which were located nearby. As such, industrial boiler systems offer great energy saving potentials, much greater than the energy saving potential in individual boilers or components of the steam systems. To facilitate investment in industrial energy efficiency, many national governments, international organizations, multilateral banks, and national governments have set industrial energy-efficient boilers as one of their targets in work programs. The Global Environment Facility is one of these organizations that have successfully financed and will finance such projects worldwide.

The GEF, a multilateral financial mechanism established in 1991, provides grants to developing countries for various projects and programs that protect the global environment. The GEF has ten agencies responsible for creating project proposals and for managing GEF projects. These agencies are Asian Development Bank, African Development Bank, European Bank for Reconstruction and Development, Food and Agriculture Organization of the United Nations, Inter-American Development Bank, International Fund for Agricultural Development, United Nations Development Programme, United Nations Environment Programme, United Nations Development Organisation, and the World Bank. The GEF agencies play key roles in managing GEF projects on the ground. More specifically, GEF agencies assist eligible governments and CSOs in the development, implementation, and management of GEF projects.

Since its inception, GEF has committed US$9 billion in grants to over 2,100 projects in more than 160 developing countries and transitional economies. More than one-third of these projects are related to climate change mitigation, and the investment of GEF funds in energy efficiency remains the largest share amount all the project subgroups in climate change mitigation (Dixon et al. 2010). One of the important investment areas in energy efficiency is in industrial boilers.

The objectives of this case study are to illustrate the GEF's role in catalyzing industrial energy-efficient boiler steam systems, provide national governments with useful information on making energy policies to promote energy efficiency in industrial sector, and guide project developers and investors on how to apply for the GEF funds in investing industrial boiler steam systems. This case study briefly reviews a GEF project that catalyzed investment in industrial energy-efficient boilers in China. It also shows opportunities of GEF's continued role in bringing about the investment in industrial efficient boiler steam system in two other countries: Vietnam and Russia. For more about the GEF investments in energy efficiency, see GEF (2009).

China is one of the selected countries for this case study because about 20 years ago, the GEF, the World Bank, and the Chinese government successfully developed and implemented a project to improve energy efficiency in industrial boilers and steam system in the country. That project greatly improved energy efficiency in Chinese industrial boilers and steam systems. Therefore, it is a good example to share with GEF project developers and agencies.

Vietnam is selected in the second case. Following the Chinese open-door policy and economic reforms, Vietnam attracted foreign capital investment in the industrial sector. Over the past few years, a large number of manufacturing industries have been relocated from China, South Korea, and Taiwan to Vietnam. The industrial technology transfer and relocation from foreign countries to Vietnam today is much similar to that from foreign countries to China about 20 years ago. This implies a great opportunity in energy efficiency in Vietnam today as in China two decades ago.

Russia is also selected in this study due to the similarities in its energy inefficiency status and carbon intensity situation today to that in China two decades ago. Figure 12.7 presents carbon intensities in China (red curve), Russia (solid blue curve), and the world (green curve). If the solid blue curve is shifted left by 20 years

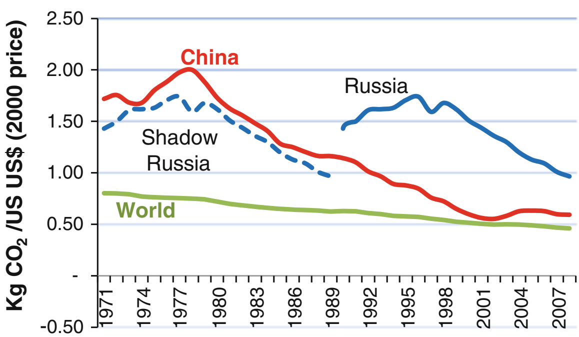


Fig. 12.7 Carbon intensities of China and Russia. *Source* Authors' data and design

and becomes the dotted blue curve that is marked "Shadow Russia," the curve would have almost the same pattern as that of the red curve. Evidently, Russia's carbon intensity change from 1990 to 2008 followed the pattern of the carbon intensity change in China from 1971 to 1990. This also implies great energy efficiency opportunities in Russia today as in China two decades ago.

Following this introduction, two sections are presented in this chapter. Section one briefly illustrates approaches and data that are used in the study for this chapter. In section two, case studies on China, Vietnam, and Russia are presented for comparison analysis. Policy implication from the analysis is shown in section three. Finally, section four presents conclusions and outlooks for the GEF to finance industrial boiler steam systems worldwide.

Methodology, approaches, and data: Methodologies used in this study cover data collection, data analysis, and cost-effectiveness evaluation. While two case studies cover four countries, each of the case studies has its own methodology, approaches, and data. These include documentation and in-depth interviews for the Chinese case study; experts' opinion and on-site assessment surveys for the Vietnamese case study, and extensive literature review for the Russian case study. Financial and economic project analyses were also used to make cost-benefit assessments for the Chinese and the Vietnamese case studies, but the details of the analysis are not shown in this chapter due to the limitation of chapter length. More details about the methodology, approaches, and data collection can be found in Yang (2006a).

Documentation and in-depth interviews: Documents were gathered to enable understanding of the historical developments in countries' energy efficiency status in industrial boilers and government's policies. For example, for the Chinese case study, the documents included project development proposal submitted by the Chinese government and the World Bank, project completion report written by the World Bank, and the project terminal evaluation report developed by the GEF evaluation office. The multi-stage and multi-source data for one case study are thought to accurately capture complex and holistic picture and report detailed views of those who provided information on the same project. In this study, the authors focus on global environment investment and benefit. Capital investment and GHG mitigation data were the major parameters for cost-effectiveness analyses. More details about the methodology and approaches can be found in Yang (2006b).

Questionnaires: A number of questionnaires were originally designed as an instrument for gathering data for the Vietnamese case study. A questionnaire about the workers' ways of using steam energy in the industrial process was widely distributed to all the workers. This questionnaire was very useful to trace steam energy flow in the boiler steam system. Another questionnaire for company's management officers on investment plan was also developed and distributed in the factory in Vietnam for project development and finance. More details about the methodology can be found in Yang (2006a).

Experts' opinions: In the Vietnamese case study, experts' opinion means a structured process for collecting and distilling knowledge from a group of operational experts in for the boiler steam system. Based on the review of documentation and interviews with energy efficiency stakeholders, the authors distributed a questionnaire for operational experts with ten proposed technologies/measures for improving energy efficiency in the boiler steam system, each with a selection criterion and a weighting mark. The questionnaire was used to gather the opinions of these operational experts on the priority of energy efficiency technology implementation in the steam system. Several rounds of discussion were held with the experts to facilitate the formation of a group judgment. More details about the methodology can be found in Yang (2009).

On-site assessment and surveys: In the Vietnamese case study again, the authors conducted walk-through surveys for the whole steam system, including boilers, economizers, water/steam pumps, to steam pipes, industrial stream/hot water loads, and condensates. During the walk-through surveys, the authors collected historical and current energy data, established a reference baseline, and identified obvious areas for improvement. The on-site assessment covered all three individual boiler systems in the factory. More details of the methodology can be found in Yang (2010).

Project cost-effectiveness analyses: In the Chinese case study, a comprehensive financial and economic analysis was undertaken by the World Bank and the Chinese government. Details about this study are available in the World Bank project development document (World Bank 1996). In the Vietnamese case study, the authors undertook financial and economic analysis by following the guideline of the ADB for project assessment (ADB 2006).

Extensive literature review: In the Russian case study, information was based on literature review. Russia is relatively new regarding the development of energy-efficient boiler steam system. The GEF has not developed any such a project, and the authors did not have any chance to do on-site assessment in Russia for this kind of case study. As such, for the Russian case study, extensive literature review was undertaken in the database of the IEA, journal articles, and publications from multilateral development banks. The following sections will show the case studies and the results.

12.2.3 China

In the early 1990s, CO_2 emissions from energy consumption accounted for about 80 % of China's total GHG emissions. The largest single source of emissions was coal combustion in medium and small industrial boilers (IBs), excluding power industrial boilers. Medium- and small-scale industrial boilers that were defined as boilers producing less than 65 tonnes of steam per hour per unit (ton/h/unit) consumed over 350 million tonnes of coal and emitted 715 million tonnes of CO_2 in China in 1990. This amount of primary energy accounted about 35 % of the country's total coal use, and the carbon emissions were equal to 30 % of total emissions from energy consumption in China.

There were an estimated half million units of industrial boilers in use outside power industry in China in the early 1990s. Over half of all IBs were between 1 and 4 ton/h/unit, and the average size was only 2.3 ton/h/unit. In contrast to other major industrialized countries, where coal-fired boilers outside of the power sector had been largely phased out, over 95 % of industrial boilers in China burn coal. Given the cost advantages of coal relative to oil, and the lack of large-scale supplies of gas in China, the use of large amounts of coal by small boilers was expected to continue well into the twenty-first century.

During the last quarter of the twentieth century, Chinese industrial boiler design and production methods were based on pre-1950 design principles. Typical efficiency levels for Chinese IBs were in a range of 60–65 %. In contrast, boilers of similar scale and application in developed countries rarely operate below 80 % net efficiency. If the thermal efficiency of the IBs in China could be raised to those of similar levels in the developed countries, coal consumption by small boilers could be reduced by 60 million tonnes per year—a savings of about 17 %. In order to harness this 17 % of energy efficiency saving potential in the Chinese industrial boilers, the GEF financed a project together with the World Bank and the Chinese government in the 1990s.

The purpose of the GEF/World Bank project was to reduce GHG emissions, as well as emissions of total suspended particulates (TSP), SO_2, and nitrogen oxides (NO_X), through (a) the development of affordable energy-efficient and cleaner IB designs; (b) the mass production and marketing of the improved boiler models that had successfully met performance criteria; and (c) the broad dissemination of more energy-efficient and cleaner IB system technologies throughout China via institutional strengthening, improved information exchange, and energy efficiency and environmental policy reform.

12.2.3.1 Design of the GEF Project

The project consisted of the following components with total project cost and GEF financing:

1. Upgrading of existing Chinese boiler models, total costs of US$53.1 million with GEF contribution of US$16.5 million
2. Adoption of new high-efficiency boiler models, total costs of US$44.1 million with GEF contribution of US$13.7 million
3. Technical assistance (TA) and training for boiler producers and consumers, total costs of US$2.1 million with GEF contribution of US$1.3 million:
4. Monitoring and evaluation, and project management, total costs of US$2.1 million with GEF contribution of US$1.3 million.

12.2.3.2 GEF Finance

The GEF financed the incremental costs of the project, calculated as the difference between the costs of the "GEF alternative" and the costs of the "baseline." The latter was defined as the costs that would otherwise be incurred by China to meet the same level of industrial boiler demand. Incremental costs faced by boiler producers to acquire advanced boiler technologies from abroad included licensing, procurement of engineering services, selected purchase of embodied technology, and their commercial demonstration. Incremental costs also included the modification of production facilities to produce new more energy-efficient boilers. The net incremental cost for boiler producers for undertaking the GEF alternative was approximately US$30.2 million. Additional costs of US$2.6 million were needed to ensure sustainability and effective implementation of the project, including monitoring and evaluation, and project management. As such, the GEF totally financed US$32.8 million in this project and leveraged US$68.6 million from the World Bank and the Chinese government.

12.2.3.3 Project Implementation

The Chinese government (the Ministry of Machinery Industry of China) was responsible for the overall implementation of the project. A project leading group (PLG) was established at project inception with the vice minister of the MMI as head of the PLG. A project management office (PMO) was organized under the PLG to oversee project preparation and coordination of various project implementation activities. The PMO had appointed two companies under MMI to assist in carrying out implementation activities: (i) The China Machine-Building International Corporation was responsible for procurement of goods and services for all subprojects; and (ii) the Beijing Clean Combustion Engineering Co. Ltd. was responsible for procurement of the rights to the advanced technology and assisted with industry-wide issues related to technology diffusion of high-efficiency and cleaner industrial boilers, product standardization, and quality control. Project grant funds were channeled through a special account set up by the Ministry of Finance of China (MOF). The MOF reimbursed all expenditures incurred by the enterprise upon approval and verification by the PMO. Disbursement for goods and project management followed the World Bank's standard disbursement guidelines.

12.2.3.4 Achievement of Objective and Outputs

The impact of the project on the Chinese industrial boiler sector has been broad and is considered substantial. The technology transfer supported by the GEF was the largest national investment in combustion efficiency improvements in the Chinese industrial boiler sector over the project period. Nine beneficiary boiler manufacturers successfully completed the transfer of international technology planned at project appraisal and built prototypes (verification models) which met the predetermined and ambitious energy efficiency and environmental performance criteria.

Eight went onto commercial production of GEF-supported boiler models and have achieved initial sales success. The GEF-financed technology transfers resulted in practical improvements in coal-fired industrial boiler designs which typically yield increases in fuel efficiency of some 5 percentage points—a large improvement for this industry. The new boilers are generally well catered to Chinese market conditions. A trademark of most of the GEF-supported boilers is the use of the diaphragm wall, which reduced about 50 % of the weight of the furnace housing traditionally made of refractory bricks while increasing the airtightness of the furnace. This was a major improvement in technology for the boiler industry in China.

In addition to the specific technology transfers, the technical assistance activities of the project broadened the impact through assistance in revision and formulation of national and sector standards for boiler and boiler house designs and environmental controls, and by strengthening professional requirements for boiler operators. This further resulted in indirect energy efficiency improvements, by enhancing quality requirements across the industry, and helping to lay a foundation for improved boiler operation. Under GEF support, one national and four sector standards were formulated and promulgated, and two national and two sector standards were revised. The project also supported a major sector effort to popularize and standardize calculation methods for industrial boiler design. The technical manual and companion computer software and database developed under this project made it possible for scientific and accurate engineering calculations to be implemented at any boiler factory, reversing the situation where only a few major manufacturers had this capacity.

The main quantitative outcome/impact indicator of the project is the annual sales of GEF-supported boilers, targeted at annual sales of a total boiler capacity of 17,940 tph at project completion and 3,000 tph for each beneficiary project boiler works within 2 years after project completion (a total of 27,000 tph of annual sales). Based on sales contracts completed by the end of October 2004, sales of GEF-supported boilers from the 8 beneficiary boiler manufacturers which have completed Phase 2 will be about 9,230 tph in 2004. The boiler works expect substantially increased sales in the coming years.

Energy efficiency gains from some of the boiler steam system components also are major. One particular successful example is the GEF-supported development and production of improved grates for chain grate boilers at the Yongning Foundry Factory in Wafangdian City. This factory sold 13,000 tph equivalent of GEF-supported boiler grates by the end of August 2004 and is projected to reach about 20,000 tph equivalent annual sales in 2004, meaning that GEF-supported boiler grates will equip around 25 % of all new chain grate industrial boiler capacity sold in China in 2004. That is very significant because the improved grates normally contribute to about 3–4 % points increase in boiler thermal efficiency.

Upgrading of existing Chinese boiler models was one of the two important tasks in the project. The tasks involved six boiler manufacturers and four auxiliary equipment makers. Five of the six boiler manufacturers have successfully adopted GEF-supported designs and manufacturing upgrades with good initial sales results. Shanghai Sifang Boiler Works and Jiangxi Boiler Works have been the most successful so far, with contracted sales of 3,150 and 2,073 tph in 2004, respectively. A particularly successful story of this component was the transfer of improved boiler grate technology from Sinto Co. of Japan to the Yongning Foundry Factory, which has become a major supplier of new, high-efficiency grates to chain grate boiler manufacturers throughout China. In short, this task has achieved its sector policy objectives in most respects and has fully achieved the physical objectives in boiler thermal efficiency and emissions requirements.

Adopting new, high-efficiency boiler models is the second task in the project. Designed to meet the emerging demand for relatively large industrial boilers in district heating and manufacturing, this task tried to cover three important market segments of the large-sized industrial boilers, including a large-capacity hot water boiler designed for district heating, a cogeneration steam boiler design suitable for coal of variable quality as well as for biomass, and a circulating fluidized bed boiler (CFBC) design that was new in China. All three technology transfers were successfully completed, met predetermined energy efficiency and environmental performance criteria, and turned into marketable products.

Technical assistance and training (TA) for boiler producers and consumers was successful. A total of 11 technical assistance/training projects were completed, covering mainly six areas: (a) establishment of a systematic training curriculum and certification procedure for boiler operators; (b) revision of technical and environmental standards and improvement of design for industrial boilers and boiler houses; (c) verification testing and technical evaluation of GEF-supported boiler models; (d) production planning and marketing assistance to project beneficiaries; (e) general sales and marketing assistance to GEF-supported boilers; and (f) replication and dissemination of GEF-supported boiler technologies. These activities helped ensure that the technology transfers actually delivered on their energy efficiency and emission reduction expectations and provided critical support for production scale-up and marketing. The TA activities generally served their function to strengthen the key links in the development and deployment of energy-efficient and less-polluting industrial boilers. One small effort—the pilot cities program designed to showcasing GEF-supported boilers—proved ineffective as the original participating cities of Shanghai and Jinan initiated policies to restrict the use of coal-fired boilers and withdrew from participation.

The institutional development impact of this project was most significant in its TA activities supporting the formulation, revision, and upgrading of national and sector technical standards for industrial boiler and boiler house designs, and the strengthening of the training curriculum and certification procedures for boiler operators. The promulgation of key new or revised standards raised the bar for design and engineering for the entire industrial boiler sector in China.

Monitoring and evaluation, and project management were also well performed in the project. Since this project included over a dozen beneficiaries across China, and each one of them had a unique set of issues, the support for project monitoring, evaluation, and management was important and necessary for achieving the project's objectives and outcomes. This component also supported the testing and evaluation of the energy efficiency and environmental performance of the verification boiler models, which was critical to assure the design quality prior to commercial production.

12.2.3.5 Global Environment Benefits

The global environment benefits from this project were calculated based on the GEF's incremental cost analysis. The main results of the original incremental cost analysis for the project were derived from the two scenarios (Baseline versus GEF alternative) for a cumulative total of 432,000 tons/h of boiler production and sales by the nine beneficiary boiler manufacturers over a 20-year span (including a 3-year development period at the beginning). The main benefit of this project is the reduction of CO_2 emissions, in addition to the local and regional benefits of reduced TSP and SO_2 emissions.

The World Bank (1996) projected that more efficient industrial boilers developed under the project were estimated to account for roughly 50–60 % of total IB output in China by the end of 2016. Direct coal savings of IB boilers produced were about 102 Mt of coal, resulting in the reduction of about 181 Mt of CO_2.

A reassessment of the project by the GEF Evaluation Office (GEFEO 2005) indicated that the project will be able to achieve about 160 Mt of cumulative CO_2 emission reduction by 2019, compared with the original 180 Mt by 2016 that was estimated at appraisal of the project development. As such, the net costs of direct CO_2 mitigations for the GEF investment in the project were US$0.205 per ton of CO_2 (indirect CO_2 reductions were not accounted). This US$0.205 per ton of CO_2 was substantially below euros 14 per ton that was used in the EU carbon market in emissions trading for CO_2 in December 2010. Given the uncertainties inherent in such estimates and the rapid rate of change in China's energy market, the GEF evaluation considered that the project objective was essentially achieved.

12.2.4 Vietnam

By the end of 2010, the number of medium and small IBs in Vietnam was estimated at about 4,000 units. About two-thirds of these boilers belonged to the government-owned companies and were registered with the Ministry of Industry of Vietnam. Of all these boilers, more than 90 % had a capacity of less than 5 tons/h/unit. Recent on-site surveys indicated that the actual energy efficiency industrial boilers were between 33–70 % for coal-fired boilers and 50–85 % for oil-fired ones. Of all the surveyed boilers, 45 % were located in the north region, mainly using coal as fuel, and 31 % were located in the south region, mainly consuming fuel oil. Moreover, approximately 39 % of oil-fired boilers and 47 % of coal-fired boilers were manufactured or built before 1985. Most of the boilers were made in China, and the rest were made in Japan, Vietnam, Russia, and the USA about 20 years ago (Yang and Cu 2004). Evidently, there is a huge potential of energy conservation in industrial boilers in Vietnam.

12.2.4.1 Design of an Industrial Boiler Project

During 2007–2008, the author undertook energy efficiency assessment for two manufacturing factories on-site in Vietnam. One of the most important tasks was to design a project for energy-efficient boilers. The data and information presented below were collected and generated on the basis of the auditing and designing of the project in one of the two factories.

In total, there were nine small industrial boilers in the audited factory. The nine boilers were installed three boiler rooms and used in three different boiler steam systems in the factory. The first room held four boilers with a total capacity of 28 tonnes of steam production per hour (2 units × 4 tons/unit/h + 2 units × 10 tons/unit/h). The total capacity of steam production of the second room was 12 tons/h (3 units × 4 tons/unit/h). The rest two boilers in the third room were diesel-fired and had a total capacity of 28 MW. The purpose of the boilers in the first two rooms was to provide steam for production processes, and the third room boilers supplied hot water in the bath/shower rooms of the factory. Each of the three boiler rooms had its own steam/heat supply system. In 2007, these boilers consumed 5,360 tonnes of heavy fuel oil and 192 tonnes of diesel.

There was a great energy saving potential in the three boiler steam systems. A typical boiler steam system consists of boilers, steam pipelines, steam molds (steam load of industrial process), steam valve, condensed water pipes, seam recovery tanks, and pumps to feed condensed water into the boilers. The more compact and closed the systems, the more efficient the systems. On-site inspection discovered that the two boiler steam systems in the factory were open and not compact. A large amount of steam/hot water (energy) was wasted in the two steam systems.

In the first steam system, the steam at the outlet of the boiler (190 °C) was directed to a workshop about 100 m away from the boilers. Before the steam was used by the industrial process (the molds), the steam temperature was about 150 °C. After being used in the industrial process, the steam and hot water (about 130 °C) were separated by a steam separation valve. The condensed hot water (about 98 °C) was then pumped to a water processing tank in the boiler room. When the condensed hot water in the tank cooled down to 90 °C, it was pumped to the boiler. Feeding in the water at 90 °C or blow was a technical requirement in the boiler design. A large amount of energy was wasted around the hot water tank, while the hot water temperature was cooling down. In addition, only 64 % (18 tons/h) of the exhausted hot water from the steam valves was pumped into the water processing tanks for recycle, and other hot water was leaked in the system. The boilers were fed with 36 % (10 tons/h) of freshwater at an average temperature of about (30 °C).

More energy was wasted in the second steam system. The whole system was open, and there was neither any recycling nor reuse of hot water in the system. In other words, the boiler was fed in with 100 % (12 tons/h) freshwater at a degree of 30 °C every time. As a result, a large amount of energy was consumed to raise feed-in water. Table 12.6 shows these figures, and Fig. 12.8 presents a diagram of the first and the second boiler steam systems in the factory.

The third stem system was simple. Two diesel boilers were heating water to supply hot water for bath/shower rooms of the factory. The author did not think it was necessary to use the boilers to heat bathwater. The required temperature for the hot water for bath/shower was about 50 °C. The hot water can be generated by using waste heat from the exhausted steam of the industrial process.

There were two major areas in the above systems for energy efficiency improvement. First, the steam system and water cycle systems should be closed to prevent the loss of steam and hot water emitted to the drainage. Second, the condensed hot water of 98 °C should pass a heat exchanger to heat water for hot water

Table 12.6 Steam and hot water balance in the two steam systems

	Steam system 1 (ton/h)	Steam system 1 (%)	Steam system 2 (ton/h)	Steam system 2 (%)
Total steam outlet	28	100	12	100
Recycled hot water	18	64	0	0
Feeding in freshwater	10	36	12	100
Hot water reuse at residential area	2.8	10	0	0
Wasted hot water	7.2	26	12	100

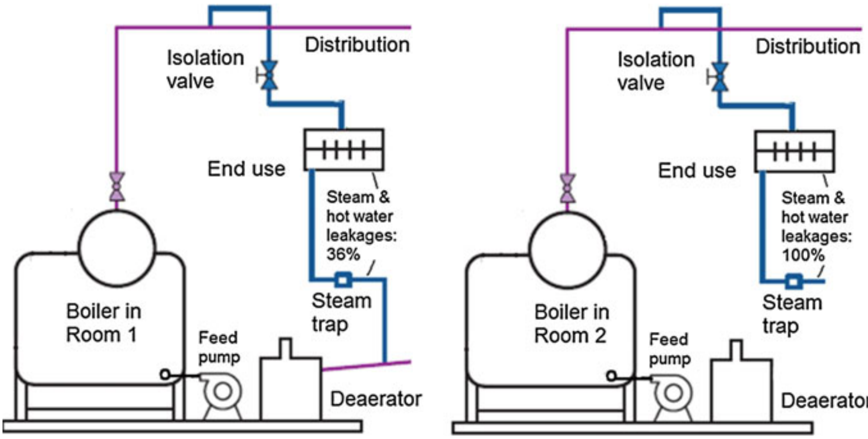


Fig. 12.8 Status of steam and hot water flow in the first two boiler steam systems. *Source* Authors' data and design

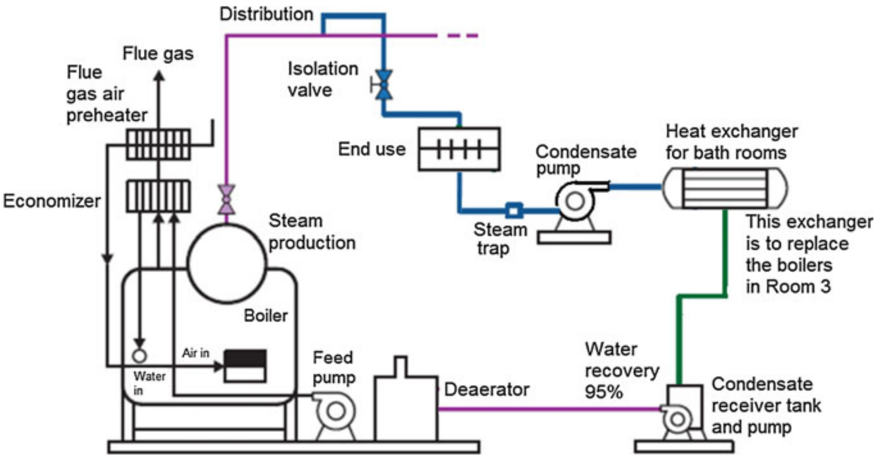


Fig. 12.9 Proposed steam and hot water flow in the first two boiler steam systems. *Source* Authors' design

supply of the bath/shower rooms before it is recycled into the boiler. To do so, two heat economizers (one at the bath/shower room and the other at the flue gas of the boilers) should be installed. The steam and hot water from the first steam system were redesigned in the following pass: boiler outlet (190 °C steam, 1 M Pa) ≫ industrial process at the workshop (155 °C steam, 0.7 M Pa) ≫ steam traps at the end of industrial process outlet (98 °C hot water) ≫ pumping the hot water to bath/shower rooms (98 °C hot water) ≫ inlet of an exchanger of shower rooms (90 °C hot water) ≫ outlet of the exchanger of the shower rooms (60 °C hot water) ≫ returning pipes of hot water with low temperature (50 °C) ≫ filter (50 °C) ≫ feeding into flue gas economizer (50 °C) ≫ feeding the water from flue gas economizer into the boilers with a pump (80 °C) (see Fig. 12.9). This new boiler system has two features. First, it stopped steam/hot water leakages in the system. Second, it uses waste heat in the flue gas of the boilers to heat water for the bath/shower rooms. With this new system, energy saving potential in the boiler systems was over 50 %.

12.2.4.2 Global Environmental Benefit

If the lifetime of the project lasts 20 years, total fuel oil and diesel savings from this project will reach 53,600 and 3,840 tonnes, respectively. This amount of fuel savings would result in a total mitigation of about 206,780 tonnes of CO_2. Since the total investment costs were at US$434,800, the cost of CO_2 mitigations for the investment in the project was about US$2.1 per ton of CO_2.

12.2.5 *Russia*

Russia has enormous energy efficiency potential. During the initial stage of transition process (1990–1995), poor energy productivity of Russian economy deteriorated even further. During 2000–2010, due to economic development recovery, energy intensity in Russia in terms of energy consumption with respect to GDP declined by about 20 %. However, despite this significant energy intensity reduction, Russia is still the least energy-efficient economy in the world.

The Russian government has been working hard on energy efficiency improvement. The G8 summit chaired by Russia in St. Petersburg in 2006 also raised the profile of the energy efficiency issues in the country. However, very few energy efficiency projects/programs took off over the past 5 years. This resistance may be explained by Russia's richness in primary energy reserves and may have made Russia's carbon intensity today similar to China's carbon intensity over 20 years ago.

According to Bashmakov (2009), Russian technical energy efficiency potential exceeds 45 % of 2005 primary energy consumption or 294 mtoe. This is about the annual primary energy consumption in France, or the UK, or Ukraine, or half of that in Japan, and over 2 % of the global primary energy consumption. Related CO_2 emission reduction potential is 50 % of the Russian 2005 emissions.

Energy efficiency potential in industrial boilers heat generation was estimated at 10.4 mtoe or 8.4 % of the 2005 consumption. Depending on the application of Kyoto flexible mechanisms, about 90 % of the technical potential is economically viable and 30–87 % is attractive for market agents. Statistically, the average efficiency of industrial boilers in Russia was 68.6 % (Bashmakov 2009).

According to a recent study by the World Bank (2008), gas-fired industrial boilers show the largest potential for improvement within the Russian industrial boiler family. Russia's boilers consumed 123.2 mtoe in 2005, of which industrial boilers consumed 66 %. Installing gas-fired industrial boilers with the best international technology, through economically and financially viable investments, can bring 5.1 mtoe in natural gas savings.

In conclusion, Russia's current situation, much similar to China over 20 years ago and like Vietnam today, has energy efficiency fruits hanging low waiting to be picked up by the right investors.

12.2.5.1 Barriers to Industrial System Energy Efficiency

There are several factors that contribute to a failure to recognize and realize the energy efficiency potential of boilers and steam systems. The first is the complexity of boilers, the systems, and the institutional structures within which they operate. The boilers and steam systems are ubiquitous in manufacturing, but their applications are highly varied. They are supporting systems. Users of these systems (industrial production practices or processes) have a significant impact on their operational efficiency. Second, operational budgets are typically segregated from capital budgets in industrial organizations, so that energy use, typically the single largest element of system equipment life cycle cost, does not influence purchase. For example, in the second system of the Vietnamese case, the steam and hot water after the production process were discharged to the sewage water system of the factory. Managers in the production process did not know the value of the energy and chemicals wasted through the discharge. Without energy-efficient procurement practices, lowest cost purchase of elements in the distribution system can result in on-going energy losses that could be avoided with a small premium at initial purchase. Third, there is lack of well-documented maintenance procedures. The energy efficiency advantages of high-efficiency components can be negated by clogged filters, failed traps, and malfunctioning valves. For another example, the authors in Vietnam discovered that about 50 % of the steam traps did not function due to lack of maintenance and test. As a result, a large amount of steam was leaked into the water system.

12.2.5.2 Policy and Strategy Recommendations

The challenge of industrial boiler steam system optimization is that it requires a new way of looking at systems and corresponding changes in the behavior of those that supply and manage them. Industrial energy efficiency policy and programmers should aim to change traditional operational practices and to integrate best practices into the institutional culture of industrial companies. Effective policies to promote industrial system optimization include the following:

1. Energy-efficient system designed for the whole factory or company should be incorporated into the long-term development of the factory or company. Whenever a new facility is proposed to be installed, it is necessary to see if it can be replaced by using the current energy supply facility.
2. Energy management standards and related training. A company or a factory should have its own management standards that fit both the overall business of the factory and the production and use of energy. Experience in China and Vietnam showed that the factory had a standard to use heavy oil or diesel (not coal at all) as fuels for boilers, but it does not have any energy efficiency standards for boiler and steam system operation.
3. System assessment policy. A policy practice needs to be established in the factory or in the company to hire energy professionals to assess energy systems annually or every 2 years. This assessment will help find best energy improvement opportunities for the company or the factory to invest.
4. Capacity building policy. A factory needs to build up its own system experts through specialized training initiatives. This training is to raise knowledge factory engineers and managers in energy savings.

5. Strategy for involving energy service companies and energy equipment suppliers. Experience in China and Vietnam has shown that the involvement of energy service companies and equipment suppliers in programmers to promote greater industrial system energy efficiency can be a highly effective strategy. Energy service companies usually have state-of-the-art energy efficiency technologies, and industrial facilities typically develop very close relationships with their supply chain. Energy service companies and energy equipment suppliers can have an important role in introducing system optimization concepts.

12.2.6 Conclusions

Energy saving potential in an industrial boiler steam system is much larger than that in a boiler or an end user of the steam. To achieve this saving potential, the use of high-efficient components in the system, good equipment maintenance, and optimization of the steam system design and operation are necessary.

The GEF successfully catalyzed investment in industrial energy efficiency boilers in China in 1990s. With US$32.8 million, the GEF leveraged US$68.6 million funds from the World Bank and the Chinese government. Total accumulated GHG mitigation from the project will be 160 million tonnes of CO_2 by 2019. This generated lowest unit cost of carbon reduction in the world: about US$0.2 per ton of CO_2 mitigation.

On-site energy efficiency auditing for a selected manufacturing factory in Vietnam discovered that investing in optimization of industrial boiler steam system design and operation in Vietnam today can generate similar results to that in China 20 years ago. Investing US$434,800 in the factory's boiler system will mitigate 206,780 tonnes of CO_2 or at a cost of US$2.1 ton of CO_2. Evidently, this is very cost-effective in terms of global environment benefit generation.

Russia's energy inefficiency current status is similar to that in China in the 1990s. Industrial boilers in Russia have about 17 % of saving margin compared to the international accepted practice in industrial boiler efficiency. The GEF is ready to catalyze investments in industrial boilers in Russia in order to pick up the lowest-hanging energy efficiency fruits.

References

Adam EJ, Marchetti JL (1999) Dynamic simulation of large boilers with natural circulation. Comput Chem Eng 23:1031–1040

Astrom KJ, Bell RD (2000) Drum boiler dynamics. Automatica 33:363–378

ADB—Asian Development Bank (2006) Handbook for borrowers on the financial management and analysis of projects, Manila, the Philippines. http://www.adb.org/documents/handbook-borrowers-financial-management-and-analysis-projects

Bashmakov I (2009) Resource of energy efficiency in Russia: scale, costs, and benefits, Energy Effici 2:369–386. doi:10.1007/s12053-009-9050-1

Chein KL, Ergin EI, Ling C, Lee A (1958) Dynamic analysis of a boiler. Trans ASME 80:1809–1819

China Electric Motor (2014) Chines energy efficient motors help emission reductions. http://www.edianji.com/news/html/hangye/11413.html. Cited on 7 June 2014

Danish Energy Management (2005) Benchmarking of electric motor efficiency levels in five Asian Countries, a study report prepared by a consulting firm in Australia

De S, Kaiadi M, Fast M, Assadi M (2007) Development of an artificial neural network model for the steam process of a coal biomass cofired combined heat and power (CHP) plant in Sweden. Energy 32:2099–2109

Dixon RK, Scheer RM, Williams GT (2010) Sustainable energy investments: contributions of the global environment facility. Mitig Adapt Strat Glob Change 16:83–102

GEF (2009) Investing energy efficiency: the GEF experience. A brochure of the GEF, Washington, DC

GEFEO (2005) GEF M&E terminal evaluation review form. GEF PMIS ID: 97, October. Prepared by Anna Viggh, Reviewed by Siv Tokle

IEA (2005) Projected costs of generating electricity. The International Energy Agency, Paris

IEA—International Energy Agency (2007) Tracking industrial energy efficiency and CO_2 emissions. ISBN: 978-92-64-03016-9. Paris

IEA—International Energy Agency (2010) Extended world energy balances. World Energy Statistics and Balances, Paris

Intelsteer Co Ltd (2006) Case study of intelligent motor controllers in the Mexico. An unpublished study report. Available from Mr Tony Chan, the CEO of Intelsteer: tony.c@intelsteer.com

Irwin G, Brown M, Hogg B, Swidenbank E (1995) Neural network modelling of a 200 MW boiler system. IEE Proc Control Theory Appl 142(6):529–536

Kalogirou SA (2000) Applications of artificial neural-networks for energy systems. Appl Energy 67:17–35

Kesgin U, Heperkan H (2005) Simulation of thermodynamic systems using soft computing techniques. Int J Energy Res 29:581–611

Kwan HW, Anderson JH (1970) A mathematical model of a 200 MW boiler. Int J Control 12 (6):977–998

Liu C, Liu J, Niu Y, Liang W (2001) Nonlinear boiler model of 300 MW power unit for system dynamic performance studies. IEEE Trans Ind Electron 2:1296–1300

MIIT—Ministry of Information and Industry of China, China motor efficiency program (2013–2015). http://www.eemods2013.org/paper/Oct28/Chinese%20workshop/Interpretation%20for%20China%20Motor%20Efficiency%20Program%20Presentation.pdf

Smrekar J, Assadi M, Fast M, Kuštrin I, De S (2009) Development of artificial neural network model for a coal-fired boiler using real plant data. Energy 34:144–52

Tysso A (1981) Modeling and parameters estimation of a ship boiler. Automatica 17:157–166

U.S. DOE (2008) Steam system efficiency optimized after J.R. simplot fertilizer plant receives energy assessment, DOE/GO-102008-2563 July 2008. www.eere.energy.gov/industry

U.S. EPA (2008) Climate leaders greenhouse gas inventory protocol offset project methodology for industrial boiler efficiency, climate protection partnerships division/climate change division office of atmospheric programs. Version 1.3. http://www.epa.gov/climateleaders/documents/resources/industrial_boiler_protocol.pdf

Usoro PB (1977) Modeling and simulation of a drum boiler-turbine power plant under emergency state control. MS thesis, Massachusetts Institute of Technology

Wisconsin Focus on Energy (2011) Steam systems—business programs, best practices. http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/steamsystems_bestpracticessheet.pdf or http://www.focusonenergy.com

World Bank (1996) China efficient industrial boilers, Project Document

World Bank (2008) Energy efficiency in Russia: Updated reserves. http://www.ifc.org/ifcext/rsefp.nsf/AttachmentsByTitle/FINAL_EE_report_Engl.pdf/US$FILE/Final_EE_report_engl.pdf

World Nuclear Association (2012) Nuclear power in China. http://www.world-nuclear.org/info/inf63.html). Cited on 7 June 2014

Yang M (2006a) Demand side management in Nepal. Energy Int J Energy 31:2677–2698. doi:10.1016/j.energy.2005.12.008

Yang M (2006b) Energy efficiency policy impact in India: case study of investment in industrial energy efficiency. Energy Policy 34(2006):3104–3114. doi:10.1016/j.enpol.2005.05.014

Yang M (2009) Air compressor efficiency in a Vietnamese enterprise. Energy Policy 37:2327–2337. doi:10.1016/j.enpol.2009.02.019

Yang M (2010) Energy efficiency improving opportunities in a large Chinese shoe-making enterprise. Energy Policy 38:452–462. doi:10.1016/j.enpol.2009.09.036

Yang M, Cu T (2004) CDM facilitating energy efficiency in Vietnam—a case study of industrial boilers. In: Proceedings published by Elsevier Ltd. ISBN: 0-08-044276-5 (2 vol set), Also available at IEA Greenhouse Gas R&D Programme, Paris. ISBN:1-898373-29-9

Zhang (2011) Overview on China motor energy efficiency standards and policies CNIS Zhang Xin 2010–1024. http://motorsummit.ch/data/files/MS_2010/ms_int_10/11_xin.pdf

Chapter 13
Conclusions and Further Studies

Abstract Low or negative cost in energy efficiency investments can be achieved in almost every developing country. These investments contribute to energy savings and GHG emission reductions. However, the low market adoption of energy-efficient technologies, coupled with the unrealized potential, implies that significant amounts of energy have not been saved cost effectively as it should be. This is referred to as energy-efficient gap that is caused by investment barriers. There are various energy efficiency barriers, but government policies can unlock these barriers. Cost-effectiveness is an indicator for sustainable investments in energy-efficient technologies; cost-effectiveness analysis is therefore a necessary approach to evaluating the feasibility of energy efficiency projects. After an energy efficiency project is approved to be cost-effective, project stakeholders may consider financing the project. However, lack of financing mechanisms in the market is a barrier to energy efficiency investment in most developing countries. Government policy and ESCOs can create effective financing mechanisms to unlock this barrier. ESCOs have been playing a very important role in energy efficiency project financing. This chapter summarizes all above areas that are related to energy efficiency and delivers conclusions and implications.

13.1 Conclusions

Energy efficiency has significantly contributed to meeting energy demand over the past 40 years. In the first 11 IEA member countries, energy efficiency has saved 1.5 billion tonnes of oil equivalent. Without energy efficiency measures implemented, consumers in these countries would have paid two-thirds more than they paid for their energy bills during 2010–2013. The actual potential of energy efficiency as the first fuel is much greater than what the world has harnessed over the past 40 years. In OECD countries alone, energy efficiency policies and technologies can generate about 2.2 billion toe to meet an average of 20 % of final energy consumption in 2030 in the sectors of buildings, equipment, lighting, transport, and industry.

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_13

Energy efficiency has also become first tool to mitigate climate change. In November 2014, both China and the USA announced their GHG emission mitigation targets. With effective energy efficiency policy and investments, this book projects that China will be able to peak its GHG emissions in 2029 at 17.1 billion tonnes of CO_2eq under a high economic development scenario, or to peak in 2027 at 12.9 billion tonnes of CO_2eq under a moderate rate of the economic development scenario. With continued regulation effort of the US EPA and investments of the private sector, the USA will reduce its total GHG emissions down to 5.2 billion tonnes of CO_2eq by 2025, or 28 % lower than the level of 2005. This carbon emission reduction will be mainly contributed from power generation sector with replacement of inefficient coal-fired power plants by efficient gas-combined-cycle technologies and cogeneration technologies.

Global fossil fuel consumption subsidies and other market failures caused barriers to energy efficiency investment. This book identified eleven major energy efficiency barriers that lock global energy efficiency investments. Energy efficiency policies, regulations, and standards could be used to remove those barriers.

Development and implementation of energy efficiency policies, regulations, and standards are highly correlated to energy prices (particularly oil prices), increasing energy demand, and environment concerns. Effective analysis for energy efficiency is an approach to testing effectiveness of capital investments in a project. While undertaking such an analysis, the analyst should include all project costs and benefits quantified as cash flows throughout the lifetime of the project from investors' perspectives. All cash flows will be discounted to the present time to calculate the net present value of the project. When an energy efficiency project is cost-effective, project stakeholders may look for project financing.

Dedicated credit lines, risk-sharing facilities, energy saving performance contracts, and leasing for energy efficiency financing can serve as effective approaches to energy efficiency project financing. These financial approaches can be a powerful tool to unlock energy efficiency project barriers. However, there is a need to further enhance these financial approaches. For example, more efforts are needed to develop a third party involved simple, efficient, and transparent M&V mechanism. In addition, some other new financial approaches that meet the changing markets are also continually developing.

ESCOs' activities in promoting energy efficiency were very successful in some countries, but not so successful in others largely due to low energy prices, weak legal and regulatory frameworks, lack of local financial market, administrative barriers, and low awareness and skepticism of the clients. Countries need to consider the following instruments while developing ESCOs projects: (1) initiatives of the national government policy to stop energy subsidies; (2) establishment of a real market based financial mechanism for ESCOs; (3) involvement of the private sector in project co-financing; (4) part of government revenue from energy tax should be invested back in energy efficiency market; (5) development of government cooperate tax exemption incentive to ESCOs; and (6) deployment of more and more new energy-efficient technologies.

New energy technologies and innovative designs are combining to create the next generation of energy-efficient technologies to meet the increasing saving targets. Continued efforts in research, development, and deployment will promote new energy-efficient technologies, including (1) lighting and appliances; (2) transportation; (3) building envelope, windows, skylights, and doors by developing innovative materials and equipment for buildings; and (4) building space heating, cooling, and water heating, will facilitate achieving large energy savings.

13.2 Future Studies in This Area

More analysis parameters may be considered in future studies on energy efficiency such as post-project impacts of energy efficiency investments. Without such analysis, the global environmental benefits due to investment cannot be fully estimated. Furthermore, a new model may be developed to integrate multiple parameters to calculate a comprehensive score for evaluating energy efficiency projects. This kind of comprehensive score could be used to rank energy efficiency projects in terms of investment cost-effectiveness, which may integrate project NPVs or IRRs with local and global environment costs and benefits.

Erratum to: Energy Efficiency

Ming Yang and Xin Yu

Erratum to: M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology, DOI 10.1007/978-1-4471-6666-5

Ming Yang affiliation was incorrect in the copyright page. The correct information is given below:

Global Environment Facility, Washington, DC, USA

The online version of the original book can be found under DOI 10.1007/978-1-4471-6666-5

M. Yang (✉)
Global Environment Facility, Washington, DC, USA
e-mail: eebook7@gmail.com

X. Yu
International Fund for China's Environment, Washington, DC, USA
e-mail: eebook7@gmail.com

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5_14

Glossary of Terms

Appliances and equipment Projects focused on the substitution and commercialization of energy efficient appliances and equipment to replace inefficient consumer appliances and equipment.

Asset acquisition This primarily refers to investment in tangible assets. It consists of both hard asset acquisition (e.g. lighting bulbs, air conditioning, industrial boilers) and soft asset acquisition (e.g. patent or license purchases).

Buildings projects Projects focused on improving energy efficiency in the built environment.

Capacity building This project activity contains a variety of objectives, which aim to build enabling environments for implementing energy efficiency projects—for example, building local human resource capacity, institutions, and regulatory frameworks.

Carbon emission factor An amount of carbon emissions per unit of final energy consumption.

Climate change A change of climate caused directly or indirectly by human activities that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods.

Co-financing The total of cash and in-kind resources committed or contributed by various governments, other multilateral or bilateral sources, the private sector, CSOs, and project beneficiaries, which are in addition to the finance provided by an investor. In a project with multiple investors, one investor's financing is co-financing to another investor, and vise-versa.

Energy efficiency Using less final energy to provide the same level of performance, comfort, and convenience, or to produce the same amount of goods and services or using the same amount of final energy to provide higher level of performance or produce more goods and services.

© Springer-Verlag London 2015

M. Yang and X. Yu, *Energy Efficiency*, Green Energy and Technology,
DOI 10.1007/978-1-4471-6666-5

Energy service companies projects Projects that build up capacities of energy companies to arrange, plan, finance, install, and monitor energy-saving technology that deliver improvements in energy efficiency.

Energy supply projects Projects designed to assist energy providers or producers in conducting energy audits, evaluating strategic efficiency improvements, and assisting in technical development and implementation.

Financing projects Projects that have focused on strengthening the financing capabilities of lenders for energy efficiency projects in order to encourage the commercial sector to invest in energy efficiency by reducing the lending risks associated with this kind of investment.

Industrial process projects Projects that have introduced and supported industrial energy efficiency improvements in industrial production.

Intangible investments Investments by projects that are designed to encourage capacity building, training, and policy-making in conjunction with developing the technical aspects of energy efficient production.

Lighting projects Projects that have reevaluated and improved energy efficiency in lighting systems, including consumer oriented products, in municipalities, commercial, or industrial premises.

Medium- and small-scale industrial boilers Boilers that produce less than 65 tonnes per hour of steam per unit.

National strategy development projects Projects that encourage the pursuit of a range of energy efficiency policy and strategy development, based on the priorities and needs of the individual country.

Tangible investments Investments by projects which are heavily oriented towards large capital investments on hard assets during project implementation, encouraging further capital investment in energy efficiency for the long-term.

Technology transfer A broad set of processes covering the flow of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations and research/education institutions.