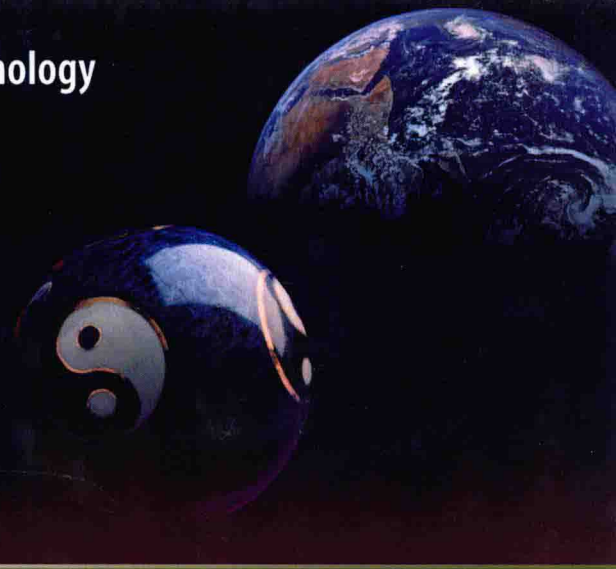
Green Energy and Technology



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Energy Efficiency

Benefits for Environment and Society

Springer

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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.

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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.

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