Economics, Law, and Institutions in Asia Pacific

Yang Liu · Farhad Taghizadeh-Hesary · Naoyuki Yoshino *Editors*

Energy Efficiency Financing and Market-Based Instruments

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Economics, Law, and Institutions in Asia Pacific

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Introduction: Energy Efficiency Financing and Market-Based Instruments

Unlocking energy efficiency potential is a key strategy for managing energy demand growth and cost-effectively reducing carbon emissions. The International Energy Agency estimates that the world will require a cumulative global investment of $24.5 trillion to tap into all available cost-effective energy efficiency potential up to 2040. Nevertheless, the global market fails in delivering this full potential of energy efficiency. This book is a collective volume of research papers aimed at enabling this trillion-dollar energy efficiency financing through financial and market-based instruments.

It is noted that more than 80 countries across the world have already taken significant strides toward improved energy efficiency with policy instruments such as energy efficiency standards and labeling schemes implemented over the last decades. However, financial and market-based instruments have a huge potential in helping public and private sectors to gain access to cost-effective strategies and technologies that could reap further energy savings. Financial and market-based instruments are essential as they deliver a price signal, which provides an incentive for firms to invest in innovation or implement more energy-efficient technologies and deliver energy savings while minimizing costs. These instruments can have significant advantages for governments, supporting the fiscal sustainability of governments' energy efficiency efforts, requiring less enforcement than regulation, and based on the market flexibility to the most cost-efficient technologies.

Financial measures include all policies and measures that assist with financing activity to improve energy efficiency. This could take the form of publicly funded loans or grants and/or subsidies for energy efficiency investment, or policies that raise funds for energy efficiency policy or encourage third-party financing of energy efficiency activities and investment, such as public–private partnerships.

Market-based instruments refer to a set of policy frameworks specifying the outcome (e.g., energy savings and cost-effectiveness) to be delivered by market actors, without prescribing the delivery mechanisms and the measures to be used. It creates a market for energy efficiency improvements or energy savings directly through instruments such as energy efficiency obligations, voluntary agreements, and auction mechanisms. Under obligations, energy utility companies are required to deliver efficient outcomes aligned with white certificate programs or energy efficiency resource standards. There could also be voluntary agreements, where users commit to deliver efficient outcomes on their own accord. Auctions are another avenue that allows bids for specific efficiency outcomes.

This book's contributors are a diverse mix of experts, practitioners, and researchers who have a great deal of experience with different dimensions of energy efficiency and financing mechanisms. This book starts with analyzing the driving forces of energy efficiency trends and investment flows in Asia and beyond. The subsequent part gives an in-depth review of energy efficiency financing and market-based instruments implemented primarily across the Asian regions. Thereafter, the authors investigate experiments with energy efficiency financing schemes in key jurisdictions and provide lessons and experience for enabling broader end-user and market player access to energy efficiency finance. The following are the specific contents of the book's chapters.

Financing energy efficiency requires a thorough understanding of historical and future energy efficiency trends. In Chapter 1, "Understanding Cross-Economy Dynamics of Energy Efficiency: Driving Factors and Stylized Patterns," Liu and Zhong investigate driving forces behind these trends across 59 major economies in the world. Despite substantial heterogeneity across economies, economy-wide energy intensity has improved overall between 2000 and 2017. The authors disentangle the role of technological effect and economic structure in shaping the patterns of energy intensity changes across countries. For the long-run distribution of energy intensity, it is found that around 21% of sample economies would stay at levels lower than the world average. This shows a persistent gap in energy efficiency across countries and highlights the importance of promoting energy efficiency financing in major emerging Asian economies, which tend to be ranked at the low end of the track.

In "Off-Balance Sheet Equity: The Engine for Energy Efficiency Capital Mobilization," Ablaza, Liu, and Llado conduct an in-depth evaluation of diverse market barriers that persist in impeding access to energy efficiency financing. They suggest that traditional debt and self-financed projects will not sufficiently promote energy efficiency investments, which most companies would regard as a noncore activity. The energy service company (ESCO) market provides an alternative to shift project risks to third parties and facilitates collateralization of energy savings and engagement of small and medium-sized enterprises. The authors review the progress of the ESCOs landscape in a diverse sample of Asian economies, including the People's Republic of China (PRC), Japan, the Republic of Korea, India, Malaysia, Thailand, Philippines, Singapore, and Taipei,China. However, the authors point out that the ESCOs usually do not have creditworthy balance sheets due to their nascent stage in most of these markets. To effectively mobilize and de-risk sizable capital for energy efficiency, there is a need to introduce new financing modalities and facilities, such as ESCO performance contracts, public–private partnership transactions, ESCO guarantee funds, super-ESCOs, and other equity channels.

In "Review of Voluntary Agreements on Energy Efficiency: Promoting Energy Efficiency Financing in ASEAN Countries," Kim and Liu provide detailed accounts of how voluntary agreements have been able to contribute to achieving energy efficiency targets in the PRC, Finland, Japan, the Netherlands, and the UK. By drawing lessons from these countries' experiences, the authors note that ambitious and realistic target settings, effectively enforceable incentives and penalties, and a strong monitoring and evaluation mechanism are three design elements of a well-functioning voluntary agreement. However, the authors also note that each country's unique conditions must be considered, and transparency must be ensured to maximize the effectiveness of voluntary agreements.

In "R&D Investments in Energy Efficiency, Economic Impact, and Emissions Abatement," Yin and Chang focus their theoretical study on the research and development (R&D) investments in supply-side energy efficiency aimed at improving efficiency in the energy production process. Their climate–economy model allows for exploring the impact of these R&D investments on economic welfare, energy transition, and climate change. With the support of simulation analysis of three emission abatement scenarios, the authors conclude that policy makers need to seriously consider R&D in supply-side energy efficiency because those investments can bring about significant economic benefits in enhancing gross domestic product and consumption.

Part II follows with specific regional case studies.

In "Nexus of Energy Efficiency and Energy Access in ASEAN: Trends and Financing Schemes," Liu and Noor review the energy efficiency financing landscape across the member states of the Association of Southeast Asian Nations (ASEAN), which have collectively committed to reducing energy intensity by 30% by 2025. This chapter discusses policy instruments and assesses innovative financing schemes in those emerging economies with diverse development levels. The authors suggest revising fossil fuel subsidies to address the nexus of energy efficiency and energy access, notably in underserved markets. Meanwhile, they recommend that transparent and accountable financing, reporting, and verification systems should be implemented to track energy efficiency financing effectiveness.

In "The Role of Fiscal Incentives and Market-Based Incentives in Promoting Energy Efficiency in the Industrial Sector: Case Studies from Asia," Sarker, Taghizadeh-Hesary, Mortha, and Saha analyze the policy strategies of four Asian countries (PRC, India, Indonesia, and Japan) with large greenhouse gas emissions and energy efficiency strategies. The chapter first reviews the type of instruments that can be used to reduce energy intensity. Then, it identifies the advantages and weaknesses and the effectiveness of the instruments discussed in the case studies. Fiscal incentives such as tax cuts and market-based instruments are shown to be efficiently reducing energy intensity. The study also highlighted the role of voluntary agreements and careful planning in successfully improving energy efficiency in the PRC.

In "Promoting Energy Efficiency through Foreign Direct Investments: Evidence from South Asian Countries," Nepal, Paija, Taghizadeh-Hesary, and Khatri investigate the impact of foreign direct investment on industrial energy intensity by incorporating economic growth, energy prices, industry value-added, and carbon emissions in the South Asian countries for the period 1990–2018. Based on empirical evidence, this chapter suggests that energy efficiency policies should be implemented for sustainable development, environmental benefits, and reducing the energy intensity to lead to long-term growth gains.

In "The Effect of Global Value Chain participation and position on Energy Efficiency in Belt and Road Countries," Sun, Acquah, Liu, and Taghizadeh-Hesary seek to add to the pioneering body of the literature on the Belt and Road Initiative (BRI) of the PRC by focusing on a sample of 36 European countries and evaluating their global value chain participation and positions before and after the BRI, and the impact on energy efficiency investment. The empirical result showed no statistically significant prediction of the global value chain participation in energy efficiency investment before and after the BRI. The chapter provides policy recommendations on fostering energy efficiency and green investments in the BRI European countries.

Part III provides country case studies.

In "District Heating Business Models and Policy Solutions: Financing Utilization of Low-Grade Industrial Excess Heat in the People's Republic of China," Liu, Hu, Dean, and Yao investigate the recent experiment of the PRC to utilize low-grade industrial excess heat to improve the energy efficiency of districting heating systems. They provide critical analysis of how various business models and heat pricing mechanisms can help overcome key barriers to investing in district heating energy efficiency projects. The authors believe that split incentives, third-party access, and the lack of energy resource mapping need to be targeted. The integration level of production, transmission, and distribution activities in a given district heating system will largely determine business models' choice.

In "Market-Led Energy Efficiency Transformation in India: A Deep Dive into the Perform, Achieve, Trade (PAT) Scheme," Sarangi and Taghizadeh-Hesary focus on analyzing market-based approaches for energy efficiency interventions, with specific thrust on the PAT scheme in India. Mapping the energy efficiency policies points to the gradual transitioning from a regulatory regime to a market-based arrangement. An analysis of the PAT scheme indicates that the scheme is designed dynamically and has enormous energy-saving potential. However, there is a lack of clarity at the policy level and operational anomalies that could generate dampening effects on future energy efficiency investments. Policy streamlining becomes imperative for the successful implementation of this scheme.

In "Financing of Energy Efficiency in Public Goods: The Case of Street Lighting Systems in Indonesia," Irsyad, Nepal, Liu, Anggono, and Taghizadeh-Hesary examine the case of financing public infrastructure for improved energy efficiency such as streetlights. While the government budget in Indonesia constrains energy efficiency financing in public facilities, the ESCO market has failed to channel private capital despite some efforts by the government. The authors give an in-depth analysis of the regulatory landscape of the ESCOs in the country. They suggest concrete measures to revise the valuation of energy savings benefit in the tendering process and the energy performance contract design. They also propose establishing a super-ESCO to unlock the potential of the private sector ESCOs and design auction mechanisms to enable the most cost-effective solutions.

In "The Viability of Green Bonds as a Financing Mechanism for Energy-Efficient Green Buildings in ASEAN: Lessons from Malaysia and Singapore," Kapoor, Teo, Azhgaliyeva, and Liu investigate why green bond financing is more widely adopted in energy-efficient green buildings in Malaysia and Singapore when compared to the rest of the world. With insightful case studies, they survey the key success factors to widen the use of green bonds to finance green buildings. They find that the market fundamentals need to ensure green bond issuance information, endorse buildings' energy performance standards, and promote local currency bond financing through domestic investors.

In "Energy Efficiency Financing in Viet Nam: Current Status and Solutions Toward Market-Based Mechanism Adoption," Dang and Taghizadeh-Hesary assess energy efficiency financing in Viet Nam and provide market-based policy recommendations. In Viet Nam, energy efficiency and conservation play an increasingly important role in serving sustainable economic development goals by tackling the threat of energy supply insecurity, while enhancing resource efficiency and effectiveness. In the national energy efficiency program, the government set the target of saving 7% of the energy consumption from 2019 to 2030. Although there are a number of fiscal measures with major government-led financing facilities dedicated to energy-efficient technologies with preferential term loans coupled with technical assistance, the energy efficiency investment in Viet Nam is still at a nascent stage. It leaves enormous room for development in the coming time. The chapter's major recommendations include focusing on the dedicated energy efficiency facilities to an energy-intensive industry, promulgating necessary regulation and policies to facilitate ESCOs, and amending and revising the electricity pricing policy to increase users' motivation to energy-efficient technologies. Besides, building a comprehensive energy efficiency database system should be more focused.

Overall, this book provides innovative and sensible directions for energy efficiency financing, focusing on developing Asia. The chapters collectively obtain recommendations for existing program designs and identify the next steps toward designing and implementing new government and private sector interventions. Many developing countries are expected to direct their efforts toward accelerated green, resource-, and energy-efficient technologies and practices across their economies. While many governments have designed and rolled out incentives and financing schemes to help the market scale up the deployment of energy efficiency solutions and services, it now becomes imperative to understand if the incentives and financing programs are indeed delivering according to their original objectives. Besides, it is essential to see how these programs can be strengthened through the remainder of their established tenures if new financial vehicles, products, or mechanisms will have to be structured and rolled out to engage the companies outside the reach of the existing programs.

We hope that this broad-ranging mix of research papers will offer valuable insights on the experiences and lessons of energy efficiency financing drawn from major jurisdictions and open our minds to innovative financing mechanisms for energy efficiency prosperity worldwide.

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Naoyuki Yoshino is Professor Emeritus of Keio University in Tokyo, Japan, and Director of the Financial Research Center (FSA Institute, Government of Japan). He obtained a PhD from Johns Hopkins University in 1979, where his thesis supervisor was Sir Alan Walters (UK's Prime Minister Margaret Thatcher's economic adviser). He worked as Assistant Professor at the State University of New York at Buffalo, Visiting Scholar at Massachusetts Institute of Technology, United States, Visiting Scholar at the Central Bank of Japan, and Visiting Professor at the University of New South Wales, Australia, and Fondation Nationale des Sciences Politiques, France. He received honorary doctorates from the University of Gothenburg, Sweden, and Martin Luther University of Halle-Wittenberg, Germany. He was also conferred with the Fukuzawa Award from Keio University for his contribution to research. He was Dean and CEO of the Asian Development Bank Institute in Tokyo (2014–2020).

Part I
Driving Factors of Energy Efficiency Financing

Chapter 1
Understanding Cross-Economy Dynamics of Energy Efficiency: Driving Factors and Stylized Patterns

Yang Liu and Sheng Zhong

Abstract Energy plays a key role in economic development. Improving energy efficiency through the use of financing instruments requires a thorough understanding of energy efficiency dynamics. This study investigates the driving factors of energy efficiency that are necessary for decision makers to focus on, and characterizes the long-run tendency of energy efficiency. This is based on a dataset covering 59 major economies in the world from 2000 to 2017. First, this chapter adopts an index decomposition approach to quantify the driving factors. The results show an overall improvement in energy efficiency between 2000 and 2017, which is driven by a technology-led efficiency effect as well as an economic structure effect, despite the heterogeneity across economies. Second, the transition matrix approach based on the Markov chain is employed to explore the steady state distribution of energy efficiency, in which around 21.23% of sample economies would stay at levels lower than the world average. The results suggest the persistent gap in energy efficiency across economies and highlight the importance of energy efficiency financing for those economies in which energy efficiency is low ranking or deteriorates, which are mostly emerging Asian economies.

Keywords Energy efficiency · Decomposition · Transition matrix · Convergence

JEL Classification Q01 · Q56 · O13

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1.1 Introduction

Energy is an essential factor of production. From an economic growth theory point of view, energy can directly affect total factor productivity, given the extended production function that incorporates capital, labor, and energy (Stern 2011). The extent of effectiveness to which energy resources are allocated and consumed can be measured by energy efficiency, that is, the inverse of energy intensity. The improvement in energy efficiency has the potential of increasing economic cost-effectiveness while reducing environmental externality, and is therefore a major macroeconomic concern for policy makers, the business community, and academic researchers. A strand of empirical literature in economics has examined the causal effect of economic performance on energy use (Ozturk 2010; Costantini and Martini 2010), but policy interventions through energy efficiency financing can decouple the growth of energy use from economic growth.

There has long been a global consensus on improving energy efficiency in the policy agenda, for example, the United Nations Sustainable Development Goal (SDG) 7 titled “affordable and clean energy” (United Nations 2015). The global tracking framework under the “Sustainable Energy for All” initiative has found that, energy efficiency progress would probably remain at only two-thirds of the rate that is required to achieve the 2030 target (World Bank and IEA 2017). If this cannot be changed, SDG 7 would be greatly challenged. To have a well-designed financing strategy, it requires a thorough understanding of the historical trends of energy efficiency. A recent report by the King Abdullah Petroleum Studies and Research Center (KAPSARC 2018) also provides an overview of the trends of industrial energy efficiency in the People’s Republic of China (PRC) and Saudi Arabia, and shows the important role of industrial strategy in reducing energy intensity.

For major emerging Asian economies, energy efficiency financing is particularly important in the pursuit of sustainable development. The example shown in Fig. 1.1 is useful. In either 2000 or 2017, the economies that are relatively low ranking (i.e., below 2 on both axes) are mostly emerging Asian economies, whereas the developed and high-income economies are more energy efficient. Between 2000 and 2017, the majority of economies achieved improvements in energy efficiency, as most data points are distributed above the 45-degree line. There are several exceptions in which energy efficiency deteriorates, which are mostly emerging Asian economies. This study seeks to outline the historical dynamics of energy efficiency and investigate the driving factors of such dynamics, which are necessary for decision makers of energy efficiency financing to focus on. Further, it explores whether the disparity in energy efficiency would be persistent.

This chapter will follow a two-step approach. First, it analyzes the historical trends of energy efficiency and driving factors, using a set of economies at different stages of development over the period 2000 to 2017. Using the Logarithmic Mean Divisia Index-I (LMDI-I) decomposition approach, this chapter quantifies the efficiency effect and economic structural effect. Despite the heterogeneity in the results across economies, this chapter confirms the pervasiveness of such empirical

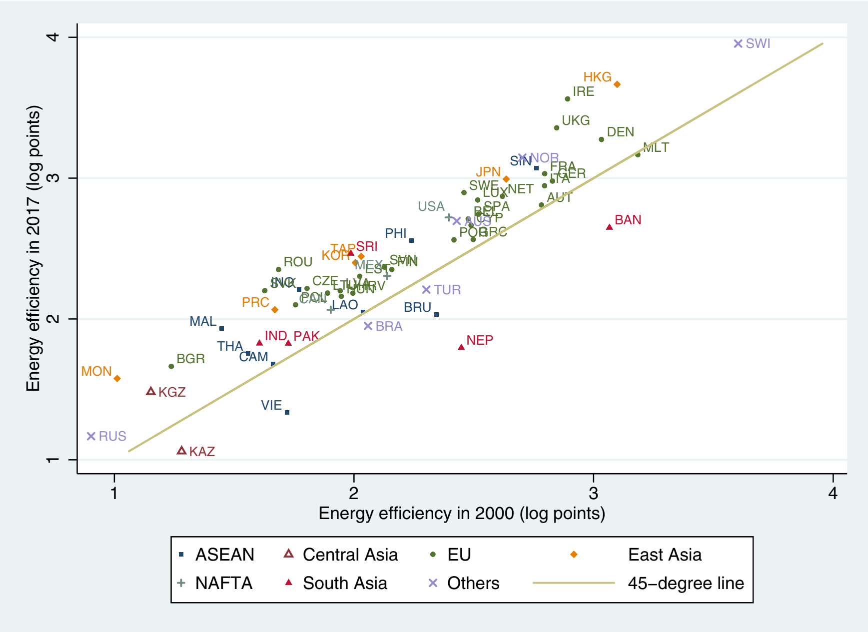

Fig. 1.1 Energy efficiency in 2000 and 2017. *Notes* Energy efficiency is calculated as the value added per unit of energy use, by summing up all sectors by economy. See Sect. 1.3.1 for a detailed discussion. The list of economies is presented in Table A1. *ASEAN* Association of Southeast Asian Nations, *EU* European Union, *NAFTA* North American Free Trade Agreement. *Source* Authors' elaboration using data from ADB–MRIO C62 (ADB 2020), and the IEA World Energy Statistics and Balances (IEA 2020)

patterns: the efficiency effect as well as the structure effect contribute to the reductions in energy intensity. Regarding the energy efficiency financing in a certain economy, the focusing area and magnitude of financing instruments should be wisely designed on the basis of the local circumstances, including both stages of economic development and technological competence. For those Asian economies in which efficiency effect is share increasing, the financing efforts towards technological change would be essential.

Further, this chapter explores the issue whether the disparity in energy efficiency between economies, as shown in Fig. 1.1, would narrow down. To do so, this chapter employs the well-established transition matrix approach that is based on the Markov chain. This approach can make full use of historical cross-economy data and characterize the long-run distribution of energy efficiency in the steady state, whereas the conventional econometric convergence methods are not able to do so. The analysis finds that the cross-economy gap in energy efficiency would be persistent, as approximately 21.23% of those economies initially distributed in the lower tails of the distribution, most of which are emerging Asian economies (Fig. 1.1), would be trapped in the low-ranking groups of energy efficiency, if no additional interventions take place. Therefore, this finding justifies the need for policy interventions through energy efficiency financing in the pursuit of inclusive and sustainable development, in particular, for the majority part of emerging Asian economies, in order to enhance financing effectiveness.

Throughout this chapter, the focus is on stylizing the pervasive empirical patterns and characterizing the steady state distribution of energy efficiency. This chapter contributes to the literature by harmonizing the most recent sectoral data and examining the common patterns of energy efficiency dynamics among a wide range of economies. It also addresses the issues of inclusiveness and equality in the study of energy efficiency. The findings in this chapter can provide useful information that can guide the direction and priority of energy efficiency financing policies. In addition, the empirical findings in this paper could serve as a starting point for economy-specific case studies in the future. The remaining parts of the chapter are structured as follows. Section 1.2 provides a brief literature review. Section 1.3 presents the historical trends of energy efficiency across economies, and derives the driving factors affecting changes in energy intensity, using the index decomposition analysis. Section 1.4 introduces the Markov chain transition matrix for the distribution of relative energy efficiency and discusses the findings. Section 1.7 concludes and discusses policy implications.

1.2 Literature Review

In the literature, there has been a series of studies focusing on the gaps between the best practices of energy efficiency applications and the actual level (Allcott and Greenstone 2012; Gillingham and Palmer 2014). Gillingham et al. (2009) summarize the common market and behavioral failures relevant to energy efficiency improvements and propose typical policy options, most of which are built on financing instruments, such as pricing strategy (e.g., real-time and market pricing) and energy and/or emissions taxes, loan programs, research and development tax credits, and public funding for early market adoption. For the United States in particular, Gillingham et al. (2006), Allcott and Greenstone (2012) provide an overview of the public financing programs related to energy efficiency, across various economic sectors. Beyond the United States cases, Retallack et al. (2018) review 10 cases across developed economies and major emerging economies, and highlight the importance of suitable policy framework and technical assistance. Following this finding, this chapter further investigates the trends and drivers of energy efficiency using a wider range of economies at different stages of economic development, which can provide stylized and quantitative information for energy efficiency financing.

There exists a rich body of literature on energy intensity or energy efficiency, most of which looks into the drivers and trends of energy intensity. The economic specialization and technological competences of an economy may change along the development process. Thus, the influential drivers that affect the growth of energy efficiency may change as well. The decomposition analyses, either the index decomposition analysis or the structural decomposition analysis, are able to distinguish between the effect due to changes in energy efficiency and the other factors driving energy consumption (Ang et al. 2010, 2015; Ang 2005). Depending on the periods and/or economies, the literature finds mixed results on the importance of energy intensity effect and economic structural effect. Some studies provide evidence of a greater role of technological change in reducing energy consumption (Voigt et al. 2014; Ma and Stern 2008; Wing 2008; Welsch and Ochsen 2005). In contrast, structural change (for example, as measured by sectoral value added shares) can play a greater role (Huntington 2010; Mulder and de Groot 2012). Some studies employ production theory to assess the effects due to technological change, changes in the capital-labor-energy ratio, output structure, and trade-facilitated technology spillovers in energy efficiency changes (Wang 2013; Wan et al. 2015). By adopting the econometric approaches from development economics, the convergence analysis in energy economics focuses on energy related indicators instead of income, and has generated a huge empirical literature (see, e.g., Duro and Padilla (2011), Jakob et al. (2012), Liddle (2009), Miketa and Mulder (2005), Mulder and de Groot (2012), Liddle (2010), Huang et al. (2017). The literature does not come to any conclusions regarding whether energy intensity converges across economies or sectors. Most prior studies support the convergence of energy intensity for the sample of developed countries, but reject the convergence hypothesis if using a broader sample including developing countries (Le Pen and Sevi 2010).

One of the fundamental questions in development economics revolves around economic inequality across economies: whether the disparity in national income between economies is growing or declining as time progresses. There has been a collection of literature applying convergence analysis. The mainstream methodology in convergence literature, either in development economics or energy economics, investigates the absolute level and growth rate of a set of variables, i.e., σ-convergence and β-convergence, as developed through a series of important works by Barro (1991), Barro and SalaiMartin (1992), SalaiMartin (1996) on economic growth. From an economic theory point of view, the σ-convergence approach seeks to confirm the declining trend in the variation of the target variable's differentials across economies. The β-convergence approach looks at the negative correlation between initial level of the target variable and its growth rate (Wan et al. 2015). However, the issue is whether an economy would eventually "stay" in the steady state if it exists.

The standard approach that tests convergence is largely based on econometric estimations: simplify the entire dynamic process of the variable under research (for example, national income per capita or labor productivity) by using its average growth rate; then estimate the effect of the initial level of the target variable on its average growth rate while controlling for some static characteristics variables. A negative regression coefficient of the initial target variable would indicate a tendency of convergence. This is because it provides some evidence that the economy in which the target variable is lower initially tends to grow faster, assuming that the growth rate tends to decline when approaching the steady state.

Such an empirical method assumes implicitly that each economy in the sample should have a smooth growth trajectory and is not affected by large external shocks except in the initial period (Quah 1993).

In addition, traditional econometric approaches will only capture the dynamics of those economies that are more influential in terms of economic size. These techniques cannot tell us anything about how the most energy intensive economies (e.g., bottom 10%) are catching up with the most energy efficient ones (e.g., top 10%). The empirical results based on the distribution approach is more informative as it shows the long run tendency on how economies in the sample are distributed.

1.3 Energy Efficiency Development Between 2000 and 2017

1.3.1 Improved Energy Efficiency

The focus of this section is on outlining the historical trends of energy efficiency. The energy efficiency indicator used in this chapter is defined as the value added per unit of energy use. To derive the energy efficiency, the sectoral value added data are obtained from the multiregional input–output tables developed by the Asian Development Bank (ADB–MRIO). The current edition of the ADB–MRIO, i.e., the 2020 release, covers 62 individual economies and the rest of the world, including a wide range of emerging Asian economies (e.g., ASEAN, Central Asia, East Asia, and South Asia), each of which contains 35 sectors. This dataset provides detailed sectoral data over time and thus is more suitable for the analysis in this chapter. It has been used in ADB's flagship publication series of *Key Indicators for Asia and the Pacific* since 2015 (ADB 2015, 2020). The full list of economies is presented in Table A1 and the full list of sectors is in Table A2. All monetary data are deflated in 2015 US dollars by using the deflators obtained from the UNCTAD Statistical Database (UNCTAD 2020).

The sectoral energy use data (in kilotons of oil equivalent, Ktoe) are taken from the International Energy Agency's (IEA) *World Energy Statistics and Balances* (IEA 2020). As the sector classifications differ between the ADB data and IEA data, this chapter defines 20 standardized sectors in accordance with classifications in the International Standard Industrial Classification Revision 4 (United Nations 2007). The sector concordance table is shown in Table A2. Due to data availability, the complete dataset covers 59 economies (excluding Bhutan, Fiji, Maldives, and rest of the world [ROW]) for 2000 and a continuous timespan from 2007 to 2017. The analysis in this chapter only considers those productive sectors that generate value added (through either producing physical goods or providing services), and thus it excludes the residential sector.

Figure 1.2 depicts the distribution of energy efficiency (Panel A) and the distribution of relative energy efficiency (Panel B) for 59 economies. As shown in

Panel A, the curve shifts downward and to the right side over time. In particular, the curve for 2017 has a longer tail to the right side of the horizontal axis. This means the energy efficiency across economies has been enhanced over years. This finding is consistent with that in Fig. 1.1. Section 1.3.2 will further investigate the factors that have led to such changes. Panel B shows the distribution of relative energy efficiency, in which each economy's level of energy efficiency is compared to the world level. The value "1" on the horizontal axis represents the world level. The curve slightly shifts to the right side as well. In particular, the area below the curve within the smaller-than-one interval shrank in 2017 as compared to 2007 and 2000, suggesting that more economies have upgraded their rankings of energy efficiency and shifted toward the world average level. Also, in 2017, the number of economies that rank as highly efficient ones (e.g., with a relative energy efficiency more than 3) increased. However, Panel B does not tell anything about how the distribution will evolve: whether the gap in energy efficiency between the least energy efficient economies and the most efficient ones tends to narrow down or increase as time progresses. Section 1.4 will further stylize patterns of the distribution in the long run.

1.3.2 Driving Factors of Energy Efficiency

The aforementioned analysis has shown the pervasive trend of improved absolute level of energy efficiency across economies between 2000 and 2017 (Panel A of Fig. 1.2). Identifying the factors that affect such changes will guide policy makers and the business community to design better strategies for energy efficiency financing. To do so, this chapter adopts the well-established Logarithmic Mean Divisia Index-I (LMDI-I) multiplicative decomposition technique (Ang 2005, 2015; Ang and Liu 2001). Specifically, the aggregate energy intensity of an economy, I, can be expressed as follows:

$$I = \sum\nolimits_i \frac{V_i}{V}\frac{E_i}{V_i} \tag{1.1}$$

where E_i and V_i indicate the energy use and value added of the $i-th$ productive sector. V is the total value added of all sectors.

Let S_i denote the value added share $\frac{V_i}{V}$ and I_i the energy intensity $\frac{E_i}{V_i}$. Then, based on Eq. (1.1), the change in aggregate energy intensity between time t and time 0, $\frac{I^t}{I^0}$, can be expressed as a product of two factors: D_{str}, the effect due to changing economic structure (as measured by the changes in sectoral shares of value added in the economy); and D_{int}, the effect due to changes in energy efficiency (as measured by the changes in energy intensity).

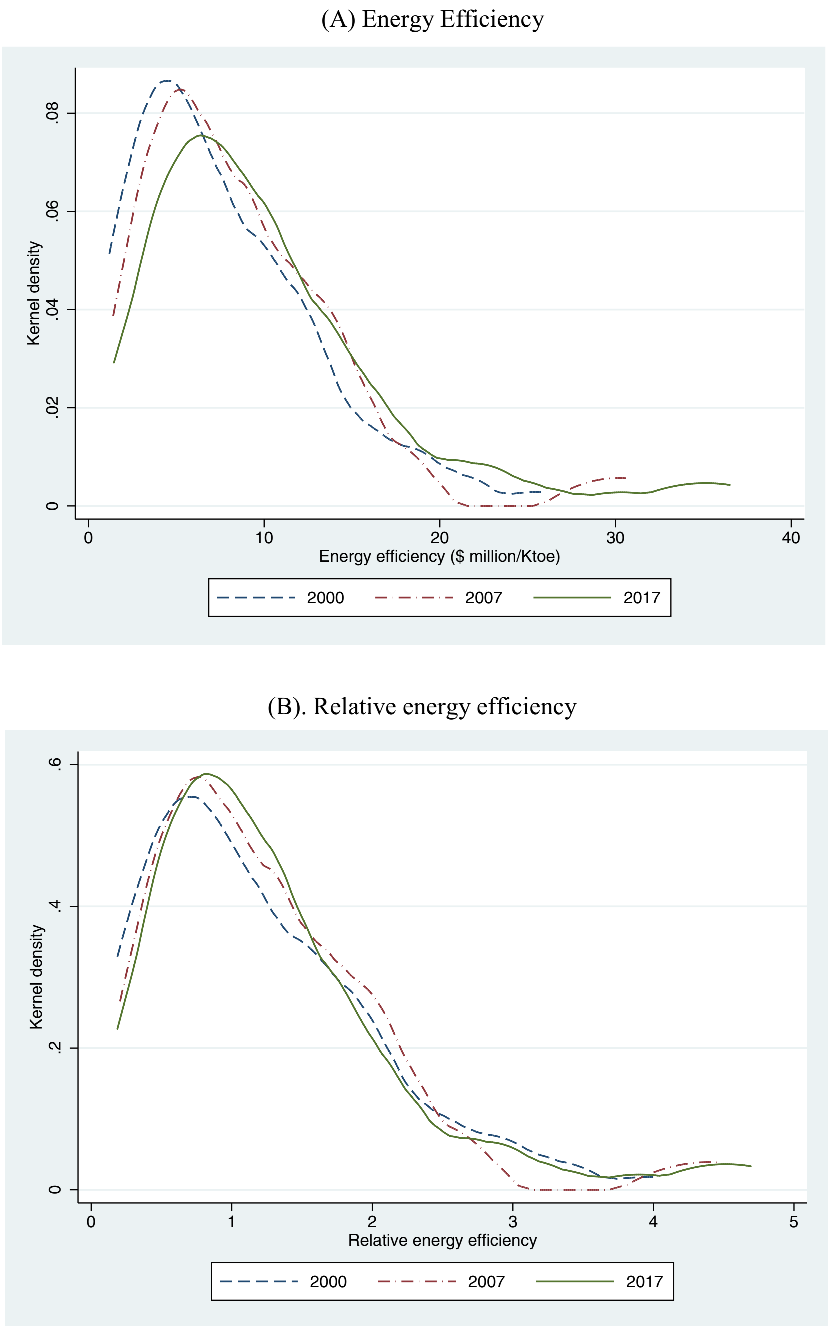

Fig. 1.2 Distribution of energy efficiency and relative energy efficiency. *Notes* Each curve in each panel is plotted by covering 59 economies in the ADB–MRIO C62 (2020 release), excluding Bhutan, Fiji, Maldives, and ROW (rest of the world). Table A1 presents the full list of economies. The relative energy efficiency in Panel B is compared to the world level, which is represented by the value "1". The density is based on the kernel estimation (Epanechnikov kernel). *Source* Authors' elaboration using data from IEA (2020) and ADB (2020)

$$D_{str} = \exp\left(\sum\nolimits_i \frac{\alpha_i}{\beta_i} \ln \frac{S_i^t}{S_i^0}\right) \tag{1.2}$$

$$D_{int} = \exp\left(\sum\nolimits_i \frac{\alpha_i}{\beta_i} \ln \frac{I_i^t}{I_i^0}\right) \tag{1.3}$$

where $\alpha_i = \left(\frac{E_i^t}{V^t} - \frac{E_i^0}{V^0}\right) / \left(\ln \frac{E_i^t}{V^t} - \ln \frac{E_i^0}{V^0}\right)$. $\beta_i = (I^t - I^0)/(\ln I^t - \ln I^0)$. Here, α_i and β_i are two weights of the $i - th$ sector.

There has been influential literature using alternative decomposition factors based on the Kaya identity, for example, the population effect and the effect due to growth of gross domestic product per capita (Zheng et al. 2020). But those alternative approaches are not able to capture the effects at the sector level, which is more relevant to energy efficiency financing. Specifically, Eqs. (1.2) and (1.3) are applied to each of all economies in the sample between 2000 and 2017. Table B1 presents the full decomposition results.

Figure 1.3 depicts the distribution of decomposition factors over the entire study period, together with the line $X = 0$. As shown in Fig. 1.3, it is evident that the most parts of both curves are located on the left side of the line $X = 0$. This indicates for most economies both structure effect and efficiency effect contribute to the decline in energy intensity. Along the larger-than-zero interval on the horizontal axis, the area below the curve of structure effect is slightly larger than that of efficiency effect, meaning that more economies achieve energy efficiency progress through economic structural changes. In particular, the peak of the curve of efficiency effect is much lower than that of the curve of structure effect. On the left side to the line $X = 0$, the curve of efficiency effect has a longer tail. This means the magnitude of efficiency effect has a larger variation among the economies in the sample.

Table B1 in Appendix B provides the full decomposition results. Among all 59 economies, 51 economies have reduced their energy intensities between 2000 and 2017. Regarding the decomposition factors, 48 economies have seen the smaller-than-one structure effect, whereas 44 economies have the efficiency effect reducing aggregate energy intensity. There is heterogeneity across economies in terms of the direction and magnitude of the two effects. In several economies in which aggregate energy intensity has increased over the sample period, sectoral energy efficiency has generally grown (except for Lithuania), whereas the structure effect lowers (or slightly increases) the aggregate energy intensity. In particular, the economies that have seen both intensity-increasing effects are all less developed economies, which are mostly located in Asia, for example, Bangladesh and Viet

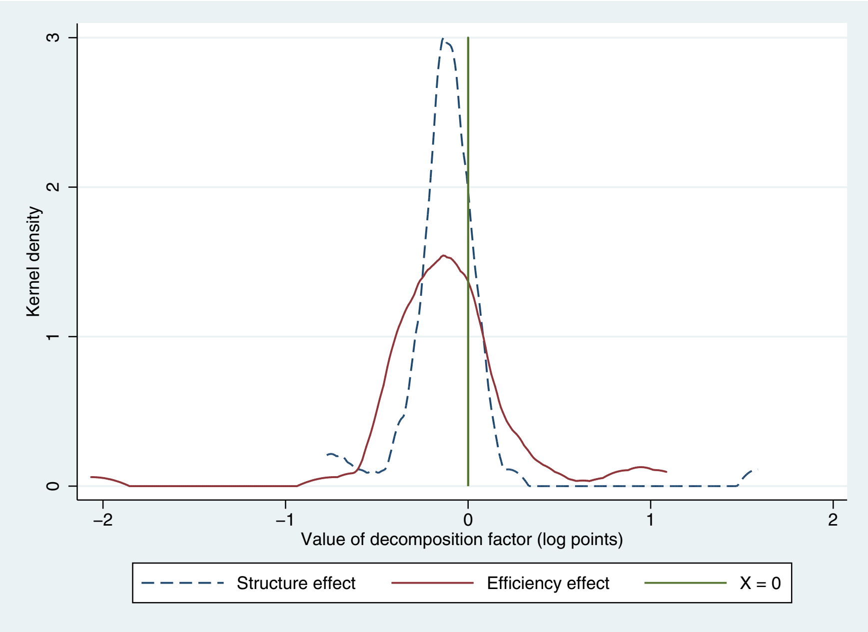

Fig. 1.3 Distribution of decomposition results between 2000 and 2017. *Notes* Each curve is plotted by covering the decomposition results (in log points) for 59 economies, excluding Bhutan, Fiji, Maldives, and ROW (rest of the world). See Table A1 for the full list of economies and Table B1 for the full decomposition results. The density is based on the kernel estimation (Epanechnikov kernel). On the horizontal axis (in log points), if the value is smaller (larger) than 0, it means the effect lowers (increases) energy intensity; a value of 0 indicates neutral effect. *Source* Authors' elaboration

Nam. For large developed and emerging economies, for example, France, Germany, India, Indonesia, Japan, the Republic of Korea, the PRC, the United Kingdom, and the United States, the efficiency effect plays a primary role in reducing the aggregate energy intensity, whereas changes in economic structures have a smaller reduction effect or even slightly drives the growth of aggregate energy intensity. There are also several economies in which the structure effect plays a larger role in reducing aggregate energy intensity, including both high-income and/or Organisation for Economic Co-operation and Development economies and emerging economies, for example, Australia, Denmark, Finland, the Lao People's Democratic Republic, Singapore, and Thailand.

The decomposition analysis in this section has several important implications for designing a proper strategy of energy efficiency financing. To improve aggregate energy efficiency, the financing effort can target technological change and innovation toward reductions in sectoral energy intensity, promoting economic development of sectors with higher energy efficiencies, or combining both. The proper strategy of energy efficiency financing should be designed based on the local circumstances of the economy, that is, the stage of economic development and technological competence. For example, the energy efficiency financing projects should invest more in technological change for those economies with an intensity-increasing efficiency effect. As more economies have the efficiency effect increasing aggregate energy intensity, there is larger potential for financing projects to improve energy efficiency through technological change. This has high relevance to sustainable development, as those economies with declining aggregate energy efficiencies are mostly less developed and emerging economies in Asia.

1.4 Distribution Dynamics of Energy Efficiency

The analysis in this section seeks to characterize the distribution of relative energy efficiency in the long run. Panel B of Fig. 1.1 reveals that there has been a trend for those energy-inefficient economies to catch up with the world average level, whereas those very efficient economies tend to progress more. If such a historical trend would be persistent in the future, it implies a disparity in energy efficiency between emerging economies and those developed ones, and thus the inclusiveness aspect of sustainable development would be greatly challenged. To analyze this, this chapter adopts the well-established distribution approach that has been extensively used in the literature of per capita gross domestic product convergence and productivity distribution.

This section will shed light on how the economies catch up in energy efficiency from the perspective of distribution dynamics. To be more precise, the analysis here focuses on how the entire distribution of energy efficiency evolves over time and converges toward a steady state. By doing so, the analysis will reflect the mobility of energy efficiency that occurs not simply within large representative economies or the initial year, but across a diversified set of economies and all years where the data are available. The results can provide useful information supporting a better design of energy efficiency financing strategy.

1.5 Distribution Approach

This chapter uses a distribution approach with the transition matrix to explore the mobility of energy efficiency. In contrast to standard econometric approaches, it is not necessary to introduce the assumption regarding the stability of growth path for the distribution approach. Specifically, the distribution of the target variable that maps its dynamics can be taken into account over the entire sample period. More research on convergence in development economics has been shift towards the laws that shape the distribution (Maasoumi et al. 2007), but the transition matrix can provide simple but intuitive characterizations of the future distribution tendency, which is the goal of this session. This method has been a standard analytical tool applied to the areas of firm productivity (Bartelsman and Dhrymes 1998; Baily et al. 1996) and income distribution (Quah 1993, 1996). Recently the distribution approach has been applied to energy studies (Cheong and Wu 2018; Li et al. 2019; Shi et al. 2020). This chapter draws on the approach similar to Li et al. (2019) and applies this approach to cross-economy dynamics of energy efficiency.

Specifically, each economy's energy efficiency is compared to the average level of the world. Thus, the energy efficiency disparity between economies is expressed in terms of the relative ranking in the world, rather than the exact magnitude. To do so, let F_t denote such a distribution of economies' relative energy efficiency in time t.

The relationship between F_t and its future distribution in time $t+1$, F_{t+1}, can be obtained through the following equation:

$$F_{t+1} = M * F_t \tag{1.4}$$

where M is a Markov transition matrix of 5 * 5 dimension.

The intuition here is that the current distribution is determined by the distribution in the previous year (i.e., Markov process). As we consider economies' rankings, all economies are allocated into five groups, from the least to the most energy efficient. Hence, the matrix M contains the probability for each economy moving from one group to another between two continuous years.

The distribution in the future time $t+s$, F_{t+s}, can be obtained through the iteration of Eq. (1.4) as follows:

$$F_{t+s} = M^s F_t \tag{1.5}$$

If the parameter s is sufficiently large, according to the property of the Markov process, matrix M will converge into a stable one, namely, the Ergodic distribution. This also means the long-run distribution F_{t+s} will not change anymore. Note that the Ergodic distribution in the analysis should only be interpreted as a characterization of the long-run tendency, rather than a precise forecast. The energy efficiency disparity between economies declines, if the majority of economies in the long run are distributed in the group in which the relative level of the world (i.e., the value 1) is located, otherwise the gap in relative energy efficiency across economies is persistent.

1.6 Distribution of Energy Efficiency in the Steady State

The data that cover a continuous timespan from 2007 to 2017 are used in the analysis in this section. All 59 major economics are classified into five groups regarding their relative energy efficiencies. The grouping bounds are based on the quantiles of their initial level of relative energy efficiencies, i.e., the relative energy efficiency in 2007, as shown in Table 1.1. By doing so, the third group contains the world level (i.e., the value one), and the numbers of economies in the groups larger or smaller than the world level would be identical. Therefore, by definition, economies in Group 1 are the least energy efficient, each of which has a relative energy efficiency below 20% quantile of the sample in the initial year, namely, 0.58, meaning 42% below the world average level. Group 3 is the group in which the world average, 1, is assigned. Group 5 is the highest relative energy efficiency group, each of which has a relative energy efficiency above top 20% of the sample, namely, 1.82, meaning 82% higher than the world average level.

Based on historical data from 2007 to 2017, the one-period transition matrix is calculated covering all 59 economies in the sample under research. Equation (1.5) is employed to derive the Ergodic distribution in the long run. These results are summarized in Table 1.2. The groups in the row and column headers represent the places in which economies are located at time t and at time $t+1$, respectively. The value in such a 5 * 5 matrix indicates the probability of economies shifting from the row group to column group after one period. Then, the last column gives the number of economies that have been located in the row group over the period 2007–2017. If the transition takes place many times, on the basis of Eq. (1.5), each row of the 5 * 5 transition matrix will converge to the same limit, which is the Ergodic distribution presented in the last row.

As shown in Table 1.2, it is not surprising that there is a persistence in energy efficiency mobility in the short run. The values on the diagonal of transition matrix range between 0.8614 and 0.9633, suggesting that an economy from a certain group is very likely to stay in the same group after one period (with a probability of at least 0.8614). For example, the economy in Group 1 has a probability of 0.9633 to stay in the same group in the next period, and only has a probability of 0.0367 to upgrade to Group 2. For those least efficient economies in Group 1, it is not possible to leapfrog to Groups 3–5 that are more energy efficient in the short run. Similar findings can also be found in Group 5, in which the most energy efficient economies are most likely to maintain their positions in the world. The economies initially located in Groups 2–4 might move up or down to neighboring groups. For Group 2 and Group 4, the probability of moving up is higher than that of moving down, suggesting a tendency of upgrading their energy efficiencies in the world. For economies in Group 3 containing the world average level, however, the probability of energy efficiency deterioration is higher.

Table 1.1 Group bounds based on relative energy efficiency in 2007, relative to world level

Group 1: (0, 0.58)	0%–20% quantile	11 economies (18.64%)
Group 2: (0.58, 0.84)	20%–40% quantile	12 economies (20.34%)
Group 3: (0.84, 1.25)	40%–60% quantile	13 economies (22.03%)
Group 4: (1.25, 1.82)	60%–80% quantile	12 economies (20.34%)
Group 5: >1.82	80%–100% quantile	11 economies (18.64%)

Notes The world level is 1 and located in Group 3. The full list of economies is presented in Table A1. Bhutan, Fiji, Maldives, and rest of the world are not included in the analysis. The group bounds are calculated on the basis of the quantiles in the initial year (i.e., 2007), and fixed over the entire period under research. By doing so, the groups are almost equal-sized only in the initial year.
Source Authors' calculation

Table 1.2 One-period transition matrix of relative energy efficiency, relative to world level

		At time $t+1$					
		Group 1	Group 2	Group 3	Group 4	Group 5	Total number
At time t	Group 1	0.9633	0.0367	0	0	0	109
	Group 2	0.0396	0.8614	0.0990	0	0	101
	Group 3	0	0.0584	0.9124	0.0292	0	137
	Group 4	0	0	0.0165	0.9256	0.0579	121
	Group 5	0	0	0	0.0574	0.9426	122
Ergodic distribution		0.1102	0.1021	0.1732	0.3059	0.3085	

Notes Group bounds are presented in Table 1.1. Group 1 is the least energy efficient group (below the bottom 20% quantile of the sample). Group 3 contains the world average level, i.e., the value one. Group 5 is the most energy efficient group (top 20% quantile of the sample). *Source* Authors' calculation

Figure 1.4 compares the initial distribution with the Ergodic distribution of economies in each group. In the initial year, each group contains about 18.64%–22.03% of all 59 economies. However, the distribution changes greatly in the long run. More economies tend to be distributed in the groups with higher relative energy efficiency. For example, most economies concentrate in the high relative energy efficiency groups, Group 4 and Group 5, in which shares grow to 30.59% and 30.85%, respectively. In the lower-than-average groups, the changes in shares show similar tendencies of energy efficiency improvement. Group 1, the group with the lowest relative energy efficiency, the share of economies drops greatly from about 18.64% to 11.02%, whereas the share decreases at a larger scale in Group 2 (from 20.34% initially to 10.21% in the Ergodic distribution). The share in Group 3, in which the world average is assigned, slightly declines to 17.32% in the steady state distribution.

The comparison clearly shows that most economies tend to improve their energy efficiencies greatly, but there is no tendency for the energy efficiency disparity to decline over time. In total 21.23% of economies in the sample would still be distributed in the groups below the world average level. The dataset in this chapter covers mostly developed economies and large emerging economies. The majority of emerging economies and the least developed economies are not considered in the current analysis, while the data are not detailed to do so.

Regarding the design of energy efficiency financing strategy, the results in this section have important implications and high relevance to sustainable development. The results highlight that if no random shocks or additional interventions take place, the disparity in energy efficiency between developed economies and those less developed ones could not be changed—eventually 21.23% of the economies that are initially the least energy efficient would be "trapped" in the same positions. Therefore, this justifies the importance of energy efficiency financing. In this regard, the interventions through diversified financing instruments, which target either technological change or economic structure change (as discussed in Sect. 1.3), are essential for those economies that are least energy efficient (mostly emerging Asian economies). More importantly, a large share of economies in the dataset are

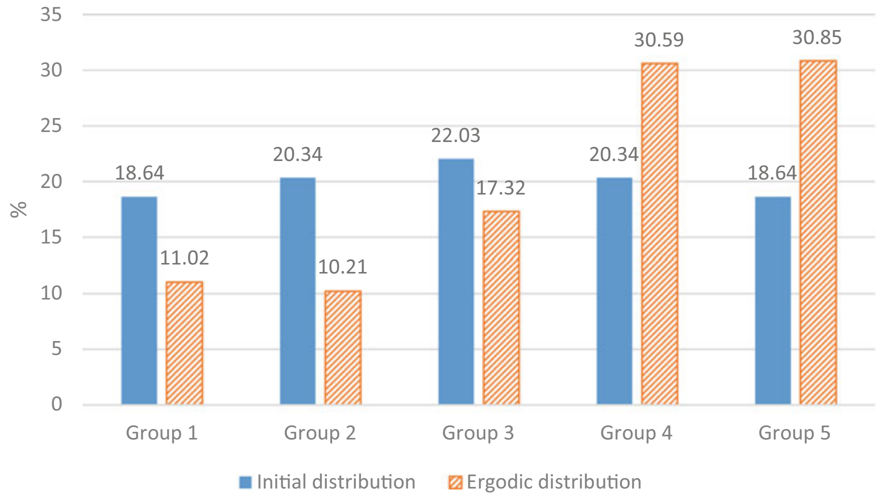

Fig. 1.4 Comparison between initial distribution and ergodic distribution *Notes* Group bounds are summarized in Table 1.1. Group 1 is the least energy efficient group. Group 3 contains the world average level, namely, the value one. Group 5 is the one with the highest energy efficiency. The initial distribution and ergodic distribution are based on Tables 1.1 and 1.2, respectively. *Source* Authors' elaboration

developed economies, i.e., those in Group 4 and Group 5, whereas the current dataset does not include those resource-rich economies in Africa and Middle East, and the majority of the least developed ones. The disparity in energy efficiency may be larger and more persistent than the estimates in this section.

1.7 Conclusions and Policy Implications

A well-designed energy efficiency financing strategy requires a thorough understanding of energy efficiency and should be evidence-based. This chapter has focused on the historical trends of energy efficiency and the steady state distribution in the long run. The analysis is based on the newly developed data of value added and energy use, covering 59 economies in the world over the timespan from 2000 to 2017, each of which contains 20 standardized sectors. The data reveal a robust trend of improvement between 2000 and 2017, in the distribution of energy efficiency as well as in the distribution of relative energy efficiency. Using the LMDI-I decomposition approach, this chapter has further identified that technology-led efficiency effect as well as economic structure change contribute to the reduction in the absolute level of energy intensity. Such empirical patterns are pervasive given a diversified set of economies, despite the heterogeneity of the factors.

Further, this chapter adopts the Markov chain transition matrix to investigate the steady state distribution of relative energy efficiency for all economies in the sample. The results highlight a persistent gap in energy efficiency between the developed economies and those less developed ones—most economies would be distributed toward either the lower end or the upper end of the whole distribution in the long run. Around 61.8% of the economies in the sample tend to shift toward the highly energy efficient groups, as a share of the sample economies are developed ones, whereas around 21.23% of the sample economies will be trapped in the least energy efficiency groups.

Two parts of the analyses feature profound implications for energy efficiency financing. First, policy interventions through various energy efficiency financing instruments would play a primary role in narrowing the gap in global energy efficiency. To enhance the effectiveness of intervention, the financing efforts should focus on those economies in which energy efficiency is relatively low-ranking or deteriorates, which are mostly emerging Asian economies. This will require a strong international cooperation mechanism in which international development institutions, such as ADB, the World Bank, and the International Monetary Fund, can play a role. Second, the technological change and innovation toward energy efficiency improvement are essential. This includes the technological change in the economies with lower energy efficiency, as well as in those energy inefficient sectors. This is also what Acemoglu (2002), Acemoglu et al. (2012) have proven by using an augmented growth model with clean and/or dirty inputs. Specifically, financing projects should target promoting the sharing of knowledge and best practice from the developed economies and/or energy efficient sectors, and more coordinated actions, such as technology transfer and harmonization of energy efficiency standards. These projects should also encourage the collaboration between the public sector, academic community and private sector. This also has been summarized in Retallack et al. (2018). Third, economic structure change can also play a role. The energy efficiency financing should optimize economic structures. This suggests promoting the development of those sectors that are energy efficient. In addition, the radical directed innovation toward energy efficiency can bring the "creative destruction" that greatly reshapes the economic structure. Fourth, a well-designed energy efficiency financing strategy should be a package of diversified and tailored instruments. The priority area and extent of the financing efforts should be based on the economic, social, and technological circumstances of the economy.

In addition, it is important to note that the approach of the Markov chain transition matrix used in this chapter does not consider the randomness and potential interventions, for example, energy efficiency financing. It is not plausible to expect that the future will strictly follow the trends of the past. In addition, changes in consumer preferences and behaviors can play a crucial role in shaping future economic structure, which has been well summarized in Allcott and Mullainathan (2010). The future distribution dynamics in energy efficiency, presented in this study, can be considered as a base case scenario if no such external disturbances occur. Thus, this study will provide a meaningful benchmark to compare with any forecasting studies. With better access to sector-specific data, future research may better assess the impact of economic structural change on the shape of cross-economy distribution in energy efficiency.

Appendix A Economies and Sectors

Table A1 Economies in ADB–MRIO

Category	Abbreviation	Economy	Category	Abbreviation	Economy
ASEAN	BRU	Brunei Darussalam	EU	AUT	Austria
	INO	Indonesia		BEL	Belgium
	CAM	Cambodia		BGR	Bulgaria
	LAO	Lao People's Democratic Republic		CYP	Cyprus
	MAL	Malaysia		CZE	Czech Republic
	PHI	Philippines		GER	Germany
	SGP	Singapore		DEN	Denmark
	THA	Thailand		SPA	Spain
	VIE	Viet Nam		EST	Estonia
Central Asia	KAZ	Kazakhstan		FIN	Finland
	KGZ	Kyrgyz Republic		FRA	France
East Asia	PRC	People's Republic of China		UKG	United Kingdom
	HKG	Hong Kong, China		GRC	Greece
	JPN	Japan		HRV	Croatia
	KOR	Republic of Korea		HUN	Hungary
	MON	Mongolia		IRL	Ireland
	TAP	Taipei,China		ITA	Italy
Others	AUS	Australia		LTU	Lithuania
	BRA	Brazil		LUX	Luxembourg
	SWI	Switzerland		LVA	Latvia
	FIJ	Fiji		MLT	Malta
	NOR	Norway		NET	Netherlands
	ROW	Rest of the World		POL	Poland
	RUS	Russian Federation		POR	Portugal
	TUR	Turkey		ROU	Romania
South Asia	BAN	Bangladesh		SVK	Slovak Republic
	BHU	Bhutan		SVN	Slovenia
	IND	India		SWE	Sweden
	MLD	Maldives	NAFTA	CAN	Canada
	SRI	Sri Lanka		MEX	Mexico
	NEP	Nepal		USA	United States
	PAK	Pakistan			

Note Myanmar is not included in the current ADB–MRIO tables. Bhutan, Fiji, Maldives, and rest of the world (ROW) are not included in the analysis in this chapter, as the IEA World Energy Statistics and Balances do not include energy use data for these economies. *ASEAN* Association of Southeast Asian Nations, *EU* European Union, *NAFTA* North American Free Trade Agreement. *Source* Authors' based on ADB–MRIO C62 (Asian Development Bank 2020)

Table A2 Sector concordance table

Sectors used in this chapter	Sector classification in IEA World Energy Statistics and Balances	Sector classification in ADB–MRIO
Sector 1	Agriculture/forestry	Agriculture, hunting, forestry, and fishing
	Fishing	
Sector 2	Mining and quarrying	Mining and quarrying
Sector 3	Food and tobacco	Food, beverages, and tobacco
Sector 4	Textile and leather	Textile and leather
Sector 5	Wood and wood products	Wood and products of wood and cork
Sector 6	Paper pulp and printing	Pulp, paper, paper products, printing, and publishing
Sector 7	Energy industry own use	Coke, refined petroleum, and nuclear fuel
		Electricity, gas, and water supply
Sector 8	Chemical and petrochemical	Chemicals and chemical products
Sector 9	Non-specified industry	Non-specified industry (rubber and plastics, manufacturing, n.e.c.; recycling)
Sector 10	Nonmetallic minerals	Nonmetallic minerals
Sector 11	Nonferrous metals	Basic metals and fabricated metal (nonferrous metals and iron and steel)
	Iron and steel	
Sector 12	Machinery	Machinery (machinery, n.e.c., electrical and optical equipment)
Sector 13	Transport equipment	Transport equipment
Sector 14	Construction	Construction
Sector 15	Road	Inland transport (road, rail, and pipeline transport)
	Rail	
	Pipeline transport	
Sector 16	Domestic navigation	Water transport (world marine bunkers and domestic navigation)
Sector 17	Domestic aviation	Air transport (world aviation bunkers and domestic aviation)
Sector 18	Non-specified transport	Other supporting and auxiliary transport activities; activities of travel agencies
Sector 19	Comm. and public services	ADB–MRIO sectors 19–22 and sectors 27–34
Sector 20	Residential	Private households with employed persons

Note Sector 20, the residential sector, is not included in the analyses. *n.e.c.* not elsewhere classified. *Source* Authors' elaboration based on IEA World Energy Statistics and Balances (IEA 2020) and ADB–MRIO C62 (ADB 2020)

Appendix B

Table B1 Full LMDI-I decomposition results between 2000 and 2017

Category	Economy	Change in energy intensity	Structure effect	Efficiency effect
ASEAN	Brunei Darussalam	1.3665	0.4612	2.9629
	Cambodia	0.9815	1.0903	0.9003
	Indonesia	0.6444	0.9567	0.6735
	Lao People’s Democratic Republic	0.9875	0.8940	1.1046
	Malaysia	0.6154	0.9269	0.6640
	Philippines	0.7288	0.7855	0.9277
	Singapore	0.7346	0.8049	0.9127
	Thailand	0.8212	0.7176	1.1443
	Viet Nam	1.4657	1.2455	1.1768
Central Asia	Kazakhstan	1.2465	0.4824	2.5843
	Kyrgyz Republic	0.7197	0.9992	0.7203
EU	Austria	0.9738	0.7990	1.2187
	Belgium	0.7920	0.7888	1.0040
	Bulgaria	0.6539	0.9641	0.6783
	Croatia	0.8283	0.8660	0.9565
	Cyprus	0.8385	0.8232	1.0186
	Czech Republic	0.6616	0.8524	0.7762
	Denmark	0.7868	0.8121	0.9689
	Estonia	0.7568	0.8292	0.9126
	Finland	0.8245	0.7106	1.1602
	France	0.7904	0.9249	0.8545
	Germany	0.8589	1.0393	0.8264
	Greece	0.9346	0.9613	0.9722
	Hungary	0.8066	0.9019	0.8943
	Ireland	0.5105	0.7380	0.6917
	Italy	0.8597	0.9919	0.8667
	Latvia	0.7733	0.8810	0.8778
	Lithuania	0.7445	1.0801	0.6893
	Luxembourg	0.7203	0.7235	0.9956
	Malta	1.0196	0.6454	1.5751
	Netherlands	0.7771	0.9118	0.8523
	Poland	0.7088	1.0550	0.6718
	Portugal	0.8647	0.9008	0.9599
	Romania	0.5131	1.0610	0.4836
	Slovak Republic	0.5638	0.8568	0.6581
	Slovenia	0.7854	1.0090	0.7784
	Spain	0.7981	0.8656	0.9220
	Sweden	0.6459	0.7904	0.8172
	United Kingdom	0.6000	0.8720	0.6880

(continued)

Table B1 (continued)

Category	Economy	Change in energy intensity	Structure effect	Efficiency effect
East Asia	Taipei,China	0.6609	0.9189	0.7192
	Hong Kong, China	0.5669	0.5455	1.0391
	Japan	0.6994	0.9320	0.7504
	Republic of Korea	0.6743	0.9086	0.7422
	Mongolia	0.5680	0.9412	0.6035
	People's Republic of China	0.6731	0.8635	0.7794
NAFTA	Canada	0.8505	0.9242	0.9203
	Mexico	0.8465	0.8664	0.9771
	United States	0.7222	0.9345	0.7729
South Asia	Bangladesh	1.5177	1.0800	1.4054
	India	0.8018	1.0258	0.7816
	Nepal	1.9202	0.8592	2.2350
	Pakistan	0.9049	0.9072	0.9974
	Sri Lanka	0.6206	4.8944	0.1268
Others	Australia	0.7657	0.7929	0.9657
	Brazil	1.1133	0.8553	1.3017
	Norway	0.6419	0.8797	0.7297
	Russian Federation	0.7674	0.8505	0.9023
	Switzerland	0.7034	1.0141	0.6936
	Turkey	1.0978	0.9988	1.0991

Notes Myanmar is not included in the current ADB–MRIO tables. Bhutan, Fiji, Maldives, and rest of the world (ROW) are not included in this table, as the IEA World Energy Statistics and Balances do not include energy use data for these economies. The product of the two factors is equal to the change in energy intensity. *ASEAN* Association of Southeast Asian Nations, *EU* European Union, *LMDI-I* Logarithmic Mean Divisia Index–I. *NAFTA* North American Free Trade Agreement. *Source* Authors' calculation

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Chapter 2
Off-Balance Sheet Equity: The Engine for Energy Efficiency Capital Mobilization

Alexander Ablaza, Yang Liu, and Mikhael Fiorello Llado

Abstract The International Energy Agency (IEA) estimates that $24.5 trillion of energy efficiency (EE) investments will be needed through 2040. Debt- and self-financed projects are expected to contribute only one-third of this capital due to multiple barriers. On the one hand, self-financed projects require upfront capital from companies' budgets to be spent on EE, which most would regard as a noncore activity. On the other hand, multiple parties face hurdles in a debt-financed project: (i) banks deem EE transactions too small and risky, and (ii) most energy service companies (ESCOs) do not have creditworthy balance sheets. Leasing agreements also have unattractive rates and extract too much project value from ESCOs and/or end users. Altogether, these constraints call for nonmainstream, off-balance sheet financial structures that will shift project risks to third parties and facilitate market benefits, such as collateralization of energy savings and engagement of small and medium-sized enterprises. Such structures include ESCO performance contracts, public–private partnership transactions, ESCO guarantee funds, super ESCOs, and other equity channels. These financing modalities require development in both the ESCO and energy performance contracting sector and EE policies, which could effectively mobilize and de-risk significant capital volumes.

Keywords Energy efficiency capital · Energy efficiency finance · Energy performance contracting (EPC) · Energy service company (ESCO) · Equity finance · Off-balance sheet finance

JEL Classification Q40 · Q42 · Q48

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2.1 Energy Efficiency Outlook

Technical efficiency improvements, defined by the International Energy Agency (IEA) as a reduction in "the amount of energy used per unit of activity," resulted in a 4% lower global demand for energy due to improvements made from 2016 to 2018 (IEA 2018a). Efficiency gains between 2015 and 2018 displaced 3.5 billion tons of carbon dioxide, equivalent to $100 billion avoided capital expenditure in 2018.

In the 2018 edition of its annual Energy Efficiency Report, the IEA revealed its Efficient World Scenario (EWS), wherein the global economy would increase twofold through 2040 at the expense of "only a marginal increase in energy demand." The key condition in making this happen is that, under the EWS, all "cost-effective energy efficiency opportunities between now and 2040" will be implemented. Compared to the New Policies Scenario (NPS), which simply accounts for existing strategies and policies under commitments per country under the Paris Agreement on climate change, the EWS forecasts only 0.3% annual growth in energy demand through 2040 (vs. 1.0% for the NPS).

In order to meet the EWS, cumulative global investment in energy efficiency through 2040 must total $24.5 trillion, which is 55% more than the investment required by the NPS (IEA 2018a). Approximately 60% will be spent on transport, 30% on buildings, and 10% on the industrial sector. These investments would need to be cost-effective, meaning project costs should be easily paid back by savings from reduced energy consumption alone. Financing can be completed through business-as-usual means, such as an outright allocation of capital expenditure by the entity in need of the energy efficiency improvement (e.g., self-financing), or debt financing provided by a third-party financial institution. Self-financing is common among large organizations, where either the scale of the energy efficiency project economically justifies upfront payment of the project cost or enough cash is available to pursue what are perceived as lower-return, "noncore" projects. Smaller organizations, however, would perceive such projects as onerous uses of resources, especially if the bulk of the cost requires early payment, and the benefits are not directly tied to the entity's core product or service. As for debt financing, its viability as a source of capital depends to a large extent on how financial institutions perceive energy efficiency projects. In Asia and the Pacific in particular, these projects are seen as risky—this perception typically results from a lack of understanding of either the technology or the contracting structure such as performance contracting). As a result, commercial lending terms are unavailable in such markets, ultimately harming energy service providers or project end users that have insufficient asset bases.

Unless new government policies and incentives are implemented and can sustain financial support of energy efficiency projects over the next few decades, or structural changes that favor business-as-usual means of financing occur, alternative modes of energy efficiency finance will be needed to meet the EWS investment requirement. Most likely, the majority of future capital would need to be mobilized through these structures, whether in the form of off-balance sheet investments or other channels such as energy efficiency funds or government-driven programs. Such modes that address various forms of risk (technological, financial, legal) of different stakeholders (energy service companies, financial institutions, end users) would be able to bridge market gaps left by relying solely on either self-financing or debt-financing energy efficiency projects. This is especially the case for Asia and the Pacific, where (i) the typical size of either an energy service provider or end user would not permit business-as-usual means of financing, and (ii) financial support from external parties (e.g., financial institutions and government agencies) are yet to have a sustainable impact on existing business models. As will be shown throughout this chapter, off-balance sheet structures, particularly energy service company (ESCO) performance contracting and other market channels, show promise in Asia and the Pacific. However, before that, it is worth examining financing mechanisms currently being used, and how such methods could not, on their own, establish an aggressive growth trend for energy efficiency capital mobilization.

2.2 Business-as-Usual Financing

During the early stages of energy efficiency market development of any country, energy efficiency projects tend to rely on two types of on-balance sheet finance: self-financing and debt-financing. These are the simplest and most reliable modes of mobilizing energy efficiency capital in markets that are still jump-starting energy efficiency finance for demonstration projects across a growing list of technologies and end user classes. Self-financing projects minimize transaction costs and insulates the end user from fluctuation in interest rates. However, equity funding can be difficult for organizations that do not have a sufficient capital base or consider energy efficiency initiatives as a noncore business activity. Although smaller amounts of capital can be allocated to low-hanging fruits such as heating, ventilation, and air-conditioning (HVAC) or lighting retrofits, economic value is lost from deferring other energy-saving opportunities.

When it comes to third-party financing, debt would be the simplest option. Frequently, banks find that cash flows from energy savings are insufficient to collateralize and secure a loan. Project finance is generally not an option for energy efficiency projects, whose average sizes are typically small. This, combined with corresponding technology risks and market risks (e.g., fluctuations in utility rates), would call for collateral from the end user's or the participating ESCO's fixed assets. As a result, the scale of energy efficiency projects and the number that can be carried out under this mode of financing become severely limited, especially for entities that are not deemed creditworthy. As regards banks and other financial institutions, de-risking their exposures from energy efficiency projects would also be necessary. Compared to debt transactions with banks, leases are processed more quickly and approvals are made more frequently. However, annual financing costs charged by leasing companies have been higher than those by commercial banks.

This failure to compete with commercial debt shifted demand for energy efficiency financing away from lease-based structures.

In developing markets such as in Southeast Asia, business-as-usual mechanisms, particularly using external debt, are a primary source of funding for energy efficiency projects. Table 2.1 shows a partial list of private and state-owned financial institutions in the region involved in energy efficiency or green financing.

On the road to the EWS scenario, however, the self-financed, debt-financed, and lease-financed modes, which are all the transactions made on the balance sheet of the energy end user, have their growth constraints. Such limitations may cap the ability of business-as-usual energy efficiency financing to mobilize no more than

Table 2.1 Partial list of pioneer financial institutions providing green financing in Southeast Asia

Country	Financial institution
Cambodia	ACLEDA Bank
Indonesia	Deutsche Bank Standard Chartered Bank Permata Bank Bank Mandiri Indonesia Eximbank
Lao People's Democratic Republic	Bank of Lao PDR
Malaysia	Maybank Berhad Bank Pembangunan HSBC Bank AmIslamic Bank Berhad Kuwait FH Bank Rakyat
Myanmar	ACLEDA MIGI
Singapore	Development Bank of Singapore Standard Chartered Bank IFS Capital Ltd. SDCL Asia
Thailand	Kasikom Bank Bangkok Bank PCL Sri Ayuthaya Bank TMB Bank Siam City Bank Siam Commercial Bank CIMB Thai EXIM Thailand
Philippines	Bank of the Philippine Islands BDO Unibank Chinabank Land Bank of the Philippines Development Bank of the Philippines
Viet Nam	Techcombank Vietin Bank

Source Ablaza (2014, updated 2020)

one-third of the $24.5 trillion capital requirement up to 2040. It is clear that more innovative financing channels will have to be employed to bridge the larger balance of the energy efficiency capital gap in the next 2 decades.

2.3 Energy Service Companies (ESCOs)

As mentioned earlier, the key limitation of business-as-usual financing is that energy efficiency equipment or infrastructure falls under the end user's balance sheet, consequently limiting access to third-party financing. Traditionally, accounting standards and treatments around the world permitted off-balance sheet financing, a structure in which the legal and economic ownership of an asset belongs to a party other than the asset's ultimate user. A typical example is an operating lease, under which the lessee does not include the asset and a corresponding liability in their balance sheet. Instead, the lessor's balance sheet reflects the leased asset, and regular rental payments are made by the lessee.

Recent updates to global accounting standards, such as the International Financing Reporting Standards (IFRS) 16, treat all leasing arrangements (including operating and finance) with multiyear tenors differently, now assigning accounting ownership to the end user, even if the legal ownership of the equipment assets remains with the lessor. While different off-balance sheet financing structures have varying cash flow and payment mechanisms depending on contractual obligations, the challenge now is to find financial structures wherein both the legal asset ownership and accounting ownership are shifted to an entity other than the energy end user. These structures are potentially vital to the acceleration of energy efficiency technology deployment in both developed and emerging markets, since the burden of upfront payment of capital and energy savings performance risks is typically transferred to a third party. These third parties are able to recoup their capital investments from guaranteed cash flows resulting from energy savings across a period of time.

In the energy efficiency industry, structures involving ESCOs are emerging as one of the most common off-balance-sheet approaches to financing. ESCOs engage in various activities depending on the client's needs, which include, but are not limited to, conducting energy audits of existing facilities, designing and implementing energy efficiency projects, identifying energy-saving opportunities, outsourcing energy infrastructure and technology, and directly financing or arranging the financing of energy projects (Ablaza 2019c). Depending on the contracting structure, ownership of the energy asset or infrastructure can reside in the ESCO (or even a third party) rather than the energy end user. A growing number of ESCOs engage in energy performance contracting (EPC), which helps manage financial and performance risk inherent in an energy efficiency project. Although a retrofit or the replacement of an equipment aims to reduce overall energy consumption, the energy savings ultimately realized by the end user may vary from what is expected or promised due to a range of technical reasons. Under an EPC, energy savings are guaranteed by the ESCO, provided that prespecified operating and maintenance procedures are adhered to (Fig. 2.1). Measurement and verification processes are also put in place to facilitate an accurate calculation of realized energy savings. In the event that the project fails to deliver the guaranteed energy savings, the ESCO compensates the energy end user with an amount equivalent to the shortfall. Performance guarantees are frequently tied to energy savings (e.g., kilowatt hour) rather than monetary savings because volatility in utility rates represents a market-based risk that should be treated outside the energy efficiency project. Contractual utility rates are set for calculating obligations between the ESCO and the energy end user.

The guarantee provision of EPCs significantly increases the certainty around project cash flows, which not only lessen performance risk for the energy end user but also improve the viability of project financing. In lieu of using an ESCO's asset base as collateral, financial institutions may view the guaranteed cash flows as effectively reducing the credit risk in a project. Another benefit of EPCs is that an energy end user would only deal with one counterparty: the ESCO. Also, as ESCOs take payment in the form of a share of the guaranteed energy savings or a fixed fee paid on a regular basis, end users avoid the financial burden of paying project capital upfront. In this structure, asset ownership is retained by the ESCO (or in some cases the financial institution providing project financing) and does not appear in the energy end user's balance sheet.

In 2018, the global ESCO market stood at $30.9 billion, 57% of which were ESCO transactions in the People's Republic of China (IEA 2018a). Commercial buildings represent the largest customer segment of the ESCO industry, followed by the industrial sector and the transport sector at a distant third. In Asian markets specifically, industry actually takes the largest share of the pie due to policies that encourage such projects. During the 2018 Asia Clean Energy Forum, the Asia–Pacific ESCO Industry Alliance estimated that 60% of the global ESCO market originates from Asia (Philippine Energy Efficiency Alliance 2018). A rapid

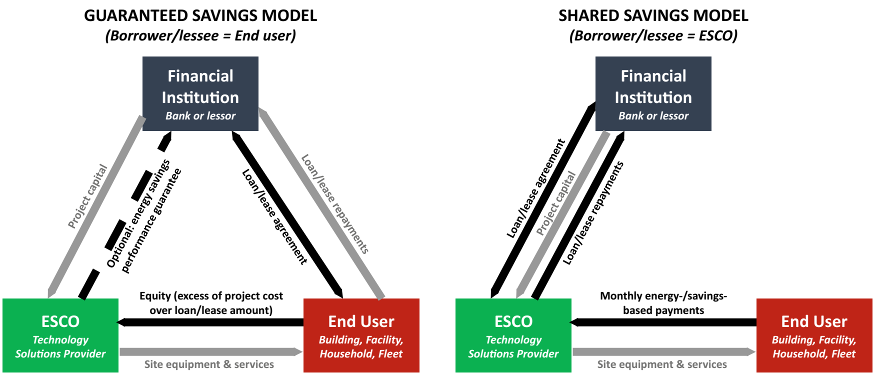

Fig. 2.1 Guaranteed savings model and shared savings model. *ESCO* energy service company. *Source* Ablaza (2019)

development is expected for ESCO markets in the region given favorable developments in policies and improvements in capacity building, underpinned by robust macroeconomic growth.

A large-scale rollout of EPCs among Asian ESCO transactions is still met with numerous challenges. Familiarity with EPC as a concept is still lacking among stakeholders. Policies in certain countries are yet to adapt in order to fully support this structure. Public procurement laws in some countries do not accommodate EPCs as they are considered a hybrid between a "pure-goods" and a "pure-service" procurement. Also, the absence of a template or set of standards for EPCs has led to a growth impediment in several markets. In numerous instances, customized public–private partnership (PPP) contracts have been employed instead.

Currently, the United States (US) accounts for over one-quarter of the global ESCO market and has still continued to slowly grow its market share over recent years. This could be attributed to its distinctive customer demographic wherein over 80% of ESCO activity is concentrated in the public sector, whereas it ranges from 10 to 40% for countries in Asia and the Pacific (IEA 2018a). Under the US Generally Accepted Accounting Principles (GAAP), EPCs are permitted to be structured as operating leases, which allow government entities to keep energy assets off their balance sheets. In Europe, where the public sector also dominates the ESCO market, similar accounting rules have also been made under the European System of Accounts. This ownership structure could potentially stimulate energy efficiency investments in Asia and the Pacific in the event that similar measures or asset recognition rules are passed. Penetrating the public sector could drastically accelerate the growth of ESCO industries given that portfolios of facilities and infrastructure can be combined in the same energy efficiency project, thereby improving project economics and management. In successful ESCO markets, guarantees and grants from either the government or a multilateral development bank also heighten access to funding by private financial institutions. This can be especially helpful for developing countries in Asia, where 98% of ESCOs lack suitable access to bank lending to be able to pursue their pipelines of ESCO-financed EPCs.

2.4 ESCO Markets in Asia

A growing list of energy markets in Asia are embracing the ESCO business model, as evidenced by the historical growth in ESCO market sizes. In most cases, ESCO sector development was bolstered by government and development programs that built technical competencies, energy end user confidence, and incentivized pioneer EPC transactions (Table 2.2).

Table 2.2 Comparative tabulation of ESCO markets in Asia

Economy	Market Size/Potential	Dominant ESCO business model	Key Barriers to ESCO industry growth	Enabling government policies and programs
People's Republic of China	$17.6 billion (2018)	Shared savings	• Lack of commercial financing for small/ medium ESCOs • Risk aversion of financial institutions against energy efficiency projects	• Required energy programs and audits for enterprises with the largest energy consumption • Capital subsidies for energy efficiency investments • Income tax exemptions for ESCOs
India	$300 million (2018)	Guaranteed savings	• Contract enforceability • Low demand for ESCO projects • Large transaction costs for smaller ESCO projects	• Partial risk guarantee facilities and other financial assistance • Standardized contract templates • ESCO accreditation process
Japan	$350 million (2017)	Shared savings	• Limited penetration into public sector	• Energy Conservation Law • Energy efficiency standards • Subsidies for energy efficiency retrofits
Malaysia	$95 million (2018)	Shared savings	• Subsidized electricity tariffs • Lack of technical know-how	• Financial incentives for energy efficiency projects under the National Energy Efficiency Action Plan • Efforts within agencies to purchase energy-efficient appliances and conduct energy audits • Capacity-building programs
Thailand	$200 million (2018)	Guaranteed savings	• Low demand due to poor understanding of the ESCO business by the private sector • Risk aversion of financial institutions against energy efficiency projects	• Energy efficiency revolving fund (EERF) • Energy Conservation and Promotion Act • Minimum Energy Performance Standards (MEPS) • Energy Efficiency Resources Standards (EERS)

(continued)

Table 2.2 (continued)

Economy	Market Size/Potential	Dominant ESCO business model	Key Barriers to ESCO industry growth	Enabling government policies and programs
Philippines	$160 billion potential (2017–2040)	Shared savings	• Lack of commercial financing for small/ medium ESCOs • Risk aversion of financial institutions against energy efficiency projects	• Energy Efficiency and Conservation Act • Mandatory energy audits for qualifying establishments • Fiscal and tax incentives for energy efficiency projects
Singapore	Target market: energy users consuming at least 54 TJ annually or Green Mark buildings	Shared savings and energy management contracts	• Slow increase in demand due to early phase-out of government incentives • Risk aversion of financial institutions against energy efficiency projects • Lack of technical know-how	• Energy Conservation Act • Green Mark scheme under the Building and Construction Authority (BCA) • Funding and grants from multiple agencies
Republic of Korea	$317 million (2018)	Shared savings	• Plateauing demand due to early phase-out of government incentives	• ESCO fund providing financing for energy efficiency projects • Mandatory energy audits
Taipei,China	$4.7 billion (2017)	Shared savings and energy supply agreements	• Energy-saving performance contracts only 22% of total ESCO business • ESCO penetration in manufacturing processes is still very limited	• Government programs to support ESCO industry and ESCO promotion • Minimum Energy Performance Standards (MEPS) • Mandatory energy efficiency rating labeling

ESCO energy service company, *TJ* terajoule. *Sources* Zhao (2019), Maekawa and Nakagami (2019), Yoon (2019), Loon and Zahari (2019), Neng (2019), Lin (2019)

People's Republic of China

The PRC accounted for 80% of energy efficiency gains between 2000 and 2017 (IEA 2018b). These efforts have helped toward achieving its unconditional 2030 target under the Paris Agreement to reduce carbon intensity by 60%–65% below 2005 levels. The ESCO Committee of China Energy Conservation Association estimates the number of ESCOs in the country to be well in excess of 6,000, most of which are categorized as small and medium-sized enterprises (SMEs) and only a handful have annual revenues above CNY1 billion. ESCO investments are highly concentrated among industrial customers, with the most common projects revolving around waste heat recovery and boiler retrofits, among others. Shared savings is the most frequently used business model, with profit splits ranging from 20/80 to 40/60 (IEA 2018b). Government policies strongly promote energy performance contracting as a primary means to develop the ESCO industry. Fiscal incentives are offered to qualifying ESCO projects as a function of displaced tons of coal-equivalent, provided that a shared savings model is used and that the ESCO finances at least 70% of the project (Ma 2013). Given that most ESCOs are SMEs, service providers frequently experience difficulty accessing capital on attractive commercial rates from banks, which still shy away from the perceived risk profile of energy efficiency projects. An International Finance Corporation study of the PRC's ESCO market revealed that while a limited 18.4% of ESCOs had access to bank lending, not more than 2% of ESCOs in the PRC enjoyed credit above $7.9 million, which would be needed for them to pursue their robust pipeline of ESCO-financed performance contracts (IFC 2013).

India

Energy efficiency is integral to reaching India's carbon reduction goals, with ESCO market potential estimated at $18 billion and 150 ESCOs currently empaneled by the Bureau of Energy Efficiency (Tewari 2019). The Alliance for an Energy-Efficient Economy represents the local ESCO and energy efficiency market players.

Of the investment potential of energy efficiency projects with a shorter payback period (less than 3 years), around half are attributed to agricultural pumping, followed by the industrial sector and commercial buildings at one quarter and one sixth, respectively (Tewari 2019). However, the latter two are the largest segments currently served by India's ESCO market. Lighting, HVAC, drives, and motors top the energy conservation measures preferred by ESCOs, which provide energy audits more frequently than full energy efficiency services. Among policies that help drive growth for the ESCO industry are demand-side management programs for the agricultural and municipal sectors, as well as regulations for the industrial sector and hotels that create more opportunities for energy efficiency. Unlike in other Southeast Asian markets, financial institutions deem energy efficiency projects to be viable sources of profit, bolstered by energy tariffs specific to commercial and industrial sectors. Furthermore, partial risk-sharing facilities (e.g., by the World Bank) exist to provide guarantees for commercial banks financing ESCO projects. Nonetheless, barriers exist that stifle further development of the industry. On top of still-lacking understanding of the business models employed by ESCOs, some potential customers choose to carry out energy efficiency projects on their own. Contract enforceability also remains an issue, as well as transaction costs that come with smaller project sizes.

Japan

The Japan Association of Energy Service Companies takes the lead in developing the country's ESCO industry. Recently, the scope of the association expanded to also cover energy management companies, which helps customers monitor and conserve their energy consumption. Among currently active ESCOs in Japan, a large majority are either a subsidiary or a new business of a larger organization or utility, while a smaller portion are stand-alone ESCOs.

The ESCO market in Japan as of 2017 was over $350 million (Maekawa and Nakagami 2019). Business models vary depending on the customer and the energy efficiency project. An initial investment can sometimes be made by the customer, and the ESCO takes a fixed portion of the guaranteed energy savings as its service charge. In instances where no upfront costs are paid by the customer, the ESCO assigns a larger percentage of the guaranteed energy savings as its service charge. Shared savings contracts represent 40% of the ESCO transactions, while less than 10% are guaranteed savings contracts. The duration of most contracts is 9–10 years due to regulation by the Ministry of Finance, and the next most-common duration is 2–4 years. Projects are typically financed 50–50 between the ESCO and the client, and the majority of both their contributions are covered by financial leases. In terms of project size, amounts vary widely from below $200,000 to above $5,000,000.

Malaysia

With the implementation of the Malaysian Industrial Energy Efficiency Improvement Project, the Malaysia Association of Energy Service Companies was incorporated. At a market size of $95 million as of 2018, Malaysia's ESCO industry primarily services nonresidential buildings (around 75% share) in the private sector. In contrast to the industry in Japan, 70% of ESCOs in Malaysia are stand-alone entities while the rest are extensions or subsidiaries of larger entities (Loon and Zahari 2019). Despite the existence of an ESCO association, a mandatory accreditation system is yet to be implemented for industry players. Shared savings contracts dominate the market at 70%, while the balance of projects is split between guaranteed savings contracts and facility management. Most contracts have a duration beyond 4 years, and project amounts are typically below $200,000.

Some 60% of ESCO projects are financed either by the customer or the ESCO, and in some instances ESCOs can secure debt from third parties (Loon and Zahari 2019). Unlike in the Philippines and Singapore, utility electricity prices are subsidized (despite a 4% annual increase in electricity tariffs), which hampers the economic viability of some ESCO projects. A lack of technical competence among ESCOs and risk aversion by financial institutions toward energy efficiency projects are among factors that hinder accelerated growth in Malaysia's ESCO industry.

Philippines

In the Philippines, energy efficiency as a key component of integrated resource planning gained traction with the recent passing of the Energy Efficiency and Conservation Act, which mandates required audits for entities meeting a minimum energy consumption level and provides fiscal incentives for energy efficiency projects. The resulting acceleration of energy efficiency projects factors into the forecast of a 182 million tons of oil equivalent reduction up to 2040, equivalent to $726 billion in savings and 45,900 megawatts in deferred installed generating capacity (Ablaza 2019b).

The Philippine Energy Efficiency Alliance serves as a nonstock, nonprofit organization that succeeded the Philippine Association of Energy Service Companies. Its 54 members come from different segments of upstream and downstream energy industries, such as power generators, utilities, equipment manufacturers, and service providers. Similarly to other Asian markets, business models are centered primarily on guaranteed savings and shared savings models, a significant number of which are for chilled water plants and other air conditioning system upgrades in large commercial and industrial facilities (Ablaza 2019a). As the public sector becomes increasingly engaged in energy efficiency efforts, a PPP–ESCO model is seen as an emerging structure to pursue such opportunities. For instance, ESCOs have partnered with local government units to implement the replacement of high-pressure sodium streetlights with light-emitting diode (LED) luminaires. Transport modernization and re-fleeting is also unfolding as a collaborative effort between national government agencies and private providers of funding and technology. The Philippine Energy Efficiency Alliance aspires to strengthen the local ESCO industry through training of industry players (e.g., in performance contracting, measurement and verification, certified energy manager certification), adoption of industry-standard performance contracting templates, and the proposed establishment of an ESCO guarantee fund or insurance facility.

Singapore

The energy efficiency and renewable energy market players in Singapore are convened by the Sustainable Energy Association of Singapore. Services offered by these ESCOs are made viable and attractive by the fact that electricity in Singapore is priced to reflect the true cost of energy. However, despite an attractive market and policy support from the government, ESCOs face challenges that hinder their industry's growth in Singapore. The ramping up of portfolios has been lackluster since most ESCOs are not creditworthy enough to take on their project pipeline.

Although energy performance contracts have already been implemented by the Building and Construction Authority and the Singapore Green Building Council to guarantee energy savings for building owners, the same is yet to be widespread between ESCOs and their customers. Given their lack of sufficient financing, ESCOs normally engage in fee-for-service projects rather than guaranteed performance based on pre-agreed contractual utility rates. As such, potential project pipelines become limited, with smaller customers unwilling to take project risks. Commercial banks in Singapore still view energy efficiency financing as risky, and thus are unable to extend secured loans to ESCOs, especially given their insufficient asset base.

Over 40% of Singapore's total electricity consumption comes from the industrial sector, which makes for a promising clientele for ESCOs (Neng 2019). However, the technical capabilities of these ESCOs cannot yet support major energy efficiency opportunities within the industrial plants. Most manufacturing companies have begun or finished tackling easy-to-implement energy efficiency opportunities (e.g., HVAC retrofits), leaving the specialized, process-related projects still in need of energy efficiency improvements. As in most other energy markets, ESCOs in Singapore are yet to reach the technical know-how needed to take on major process efficiency projects and receive buy-in from these industrial players.

Republic of Korea

ESCOs in the Republic of Korea are registered under the Ministry of Trade, Industry, and Energy, pursuant to Article 25 of the Energy Use Rationalization Act and Article 30 of the Enforcement Decree of the same act. The Korea Association of ESCO reported that the ESCO industry started with pure lighting projects within buildings, then later diversified over recent years to process-related improvements, waste heat recovery, boilers, cogeneration, and distributed generation (Yoon 2019). The customer demographic has also changed significantly over the past decade. The share of buildings decreased from 23% in 2008 to 7% in 2018 in favor of the public sector, which rose from 20 to 33%. Generally, guaranteed savings contracts are favored over shared savings contracts. The Republic of Korea's ESCO industry enjoyed early success, with its market size trebling from $116 million in 2008 to $317 million in 2018. However, due largely to the government decision to discontinue fiscal incentives to ESCOs, the market size rapidly shrank in 2019.

Thailand

In its 20-year energy efficiency plan through 2030, the Thai government tagged ESCOs as "vital mechanisms" for consulting and implementing energy efficiency projects. The local ESCO industry began in 1999, when the Global Environment Facility pilot project conducted energy audits across four industrial facilities. Thirteen years later, the Thai ESCO Association was created to serve as an information hub for stakeholders and take charge of the accreditation of ESCOs, among others. There are currently 69 ESCOs in the association's registration list. The market size is estimated to be between $200 million and $350 million (Vechakij 2014). Nearly all ESCO activities occur in the private sector, around 75% of which are industrial customers. Almost 80% of contracts employ a guaranteed savings model, and two-thirds of the rest use a shared savings model. Similarly to other Asian markets, the Thai ESCO industry experience lacks (i) access to funding by financial institutions, (ii) technical know-how, especially for more sophisticated energy efficiency projects, and (iii) customer demand due to minimal understanding of the ESCO business.

Taipei,China

The Bureau of Energy under the Ministry of Economic Affairs made minimum energy performance standards and energy efficiency rating labeling mandatory. This created a runway for growth in energy efficiency projects. The energy service association serves as a collaborative platform for ESCOs engaged in a variety of energy-saving services, such as those involving HVAC, lighting, boilers, air compressors, and energy management systems. From its beginnings in 2005, the ESCO market boomed to $4.7 billion in 2017 (Lin 2019). Guaranteed savings and shared savings contracts typically have a duration of 3–5 years and 4–8 years, respectively.

2.4.1 Super ESCOs

Super ESCOs are large-scale ESCOs established and capitalized by the government, aimed towards achieving a scale capable of taking on multiple EPCs and gaining access to competitive lending terms from financial institutions (Fig. 2.2). This portfolio approach enjoys risk diversification similar to that of energy efficiency investment vehicles and facilitates capacity building and streamlining for other ESCO players in terms of procurement, energy performance contracting, technical competence, and so on. Today, super ESCOs have either been established or are evolving in seven countries: Armenia (R2E2 Fund), Belgium (FEDESCO), the PRC (Fakai Scientific Services Corporation), Croatia (HEP ESCO), India (EESL), Saudi Arabia (Tarshid), and the United Arab Emirates (Etihad ESCO) (Ablaza 2019c).

The void that super ESCOs can fill is the large-scale implementation of projects, which face numerous barriers. In the public sector, public agencies have limited technical capacity for conducting energy audits and procurement rules make performance contracting difficult (Limaye and Limaye 2009). As for the private sector, project financing is a preferred approach by end users and ESCOs but not by financial institutions (especially when it comes to energy efficiency projects). As

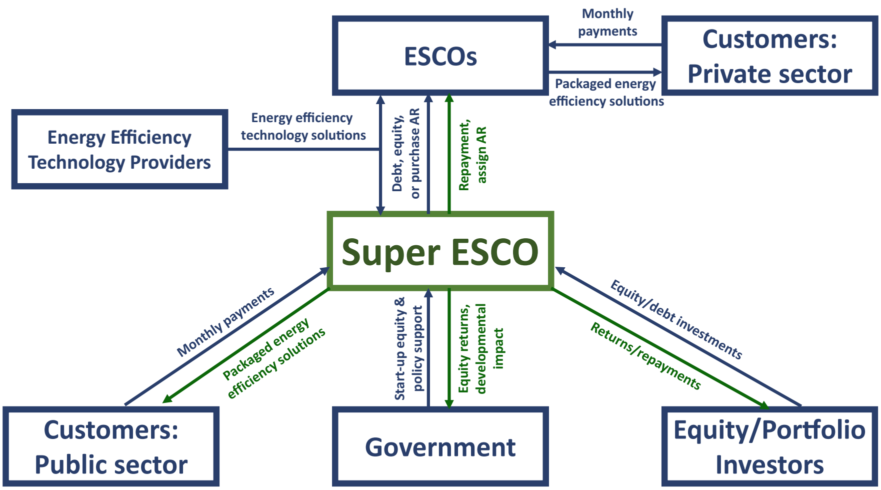

Fig. 2.2 Super ESCO structure proposed for Southeast Asian markets. *AR* accounts receivables, *ESCO* energy service company. *Source* Ablaza (2014)

most of the undertaken projects are currently in the public sector (e.g., street-lighting, public building retrofits, and irrigation pump replacements), super ESCOs have the potential to invest resources in the deliberate de-risking and generation of ESCO project pipelines across and beyond industrial plants and commercial buildings. Such resources would also include energy audit and design expertise. As a government-capitalized entity, super ESCOs could also overcome procurement issues regarding performance contracting. On their scale, super ESCOs could potentially serve as a source of third-party equity financing, particularly for greenfield and brownfield EPCs of privately owned ESCOs, thereby allowing the latter to recapitalize and pursue new EPCs. Furthermore, super ESCOs could provide technical advisory support to local financial institutions to help the latter develop financial products geared towards energy efficiency. Confidence of financial institutions in energy efficiency projects can also be improved using credit enhancement and risk management products provided by super ESCOs.

Super ESCOs can also function as the development pillar of a local ESCO industry through providing technical training, sharing best practices, and establishing contracting standards or templates. They can devise marketing campaigns and demonstration projects to heighten awareness of end users regarding the ESCO concept (Limaye and Limaye 2009). To carry out these functions, a super ESCO must not directly compete with private ESCOs, but rather create a shared platform for their growth.

2.5 Market Enablers

Market features or structures exist to either stimulate larger amounts of capital mobilization or manage risk, thus encouraging greater levels of industry participation to benefit of ESCOs, among others. Unlike parties involved in business-as-usual or off-balance sheet financing, providers of funding or guarantees under such special structures do not necessarily gain ownership of the asset but are nonetheless crucial in enabling certain energy efficiency transactions.

2.5.1 ESCO Guarantee Fund

Under energy performance contracting, there are risks that financial obligations may not be met, resulting from financial shortfalls or technological underperformance by the counterparties. An ESCO guarantee fund functions as an insurance facility that provides various types of guarantee cover depending on the financial obligation being insured (Ablaza 2019c). For example, the fund can mitigate the energy performance guarantee risk of the counterparty financing the majority of the upfront capital (whether it be the ESCO, end user, equipment lessor, or third-party investor) by partly or wholly covering deficits in net cash flows required under the EPC. Counterparty or customer credit risk can also be insured by the fund, addressing instances when guaranteed payables to the ESCO cannot be fully paid by the end user. The development of such insurance markets reduces uncertainties in EPC cash flow streams, paving the way for collateralization or even securitization. ESCOs will also be able to undertake projects with less creditworthy customers, or those belonging to more financially volatile industries.

2.5.2 Risk-Sharing Facilities

Grants and fiscal incentives are among the most common ways that governments mobilize capital to energy efficiency projects. Another method is to create risk-sharing facilities (RSF), wherein credit risk from energy efficiency debt financing (whether for a single project or a full portfolio) is shared between the government and another financial institution (Ablaza 2019c). In a single-tranche RSF, the government may elect to take the majority of the risk (e.g., 70%–80%) and leave the balance to the other financial institution. The structure can be further customized to manage the risk of the government investment. Under a two-tranche RSF, the government can evenly split the first wave of credit losses with the other financial institutions, but take the majority of the exposure (e.g., 70%–80%) of any incremental losses thereafter. Such a structure would insulate the government from losses that aggregate from relatively smaller underpayments across multiple ESCO customers, but still create an economic incentive for private financial institutions to participate in the financing process.

2.5.3 Long-Term Financing Sources

End users of energy efficiency projects can source funding from third parties via either equity or debt investment. Financial institutions such as commercial banks initially provided equity funding, however they increasingly turned toward debt investment for risk management purposes. Multilateral development banks may offer long-term debt financing to stimulate energy efficiency markets, especially in emerging economies. Since these funds are designed to support pipelines of energy efficiency projects, their investment horizons easily exceed the typical contract duration of a project. Official development assistance funds (ODAs), for example, can flowed into either large-scale government programs or private investment vehicles, which ultimately retain ownership of the asset infrastructure. Especially in the case of ODAs, financing is provided at near-wholesale rates, typically set at a small spread above interest rate benchmarks. Although ODAs have predetermined criteria for approving funding applications, such affordable financing is valuable to ESCOs and end users that lack the asset base to qualify for commercial loans.

2.5.4 Portfolio Investments

The use of off-balance sheet equity significantly reduces financial risk for the end users. However, the additional risk borne by third-party equity providers, especially for large-size energy efficiency projects, might render unacceptable risk-return trade-offs and limit overall capital mobilization from this source. This can be addressed through aggregating various projects under a portfolio that would effectively improve the risk-return trade-off through diversification. Similar to conventional private equity structures, an equity vehicle can be used to pool equity (and even debt) funds, which would then be used to invest in multiple energy efficiency projects via a wholly owned project or asset management company. The project company collects repayments undthe large-scale implementationer energy service agreements with commercial or industrial end users, pays operation and maintenance fees to technology and service providers, and flows the resulting net returns back to the original equity and debt investors after the equity vehicle deducts its asset management fee (Fig. 2.3). Projects within the commercial, industrial, and public sectors are selected based on a defined investment philosophy (e.g., in terms of technology market, required payback, client profile, etc.) and are subject to technical, financial, and legal due diligence by the project company. Scoring systems reflecting the investment philosophy are sometimes used to filter and rank numerous prospective projects.

Although still infrequent, this financing structure is already being used around the world. Based in the United Kingdom, Sustainable Development Capital LLC operates through numerous investment vehicles in Ireland, Asia, North America, Europe, the Middle East, and Africa. Projects include operational energy efficiency, decentralized energy projects, development- and construction-stage energy efficiency, and distributed energy. Hannon Armstrong, a US public company based in Maryland, invests not only in behind-the-meter and grid-connected projects but also in energy infrastructure such as transmission lines and distribution systems. As an investment partner of technology providers and ESCOs, Climargy was recently established as one of the first investment vehicles in developing Asia to provide equity funding for energy efficiency upgrades, distributed generation, and energy storage projects through shared savings performance contracts and energy-offtake agreements.

The existence of nonbank portfolio equity vehicles actually broadens the bankable investment opportunities for debt providers such as commercial and development banks, or corporate equity partners such as energy developers who wish to diversify their portfolios. Compared to their underlying projects, these "fund-like" equity vehicles become the more creditworthy investees of the debt and equity providers. These vehicles do not therefore necessarily displace the debt finance volumes supposedly bridging the long-term energy efficiency capital gap,

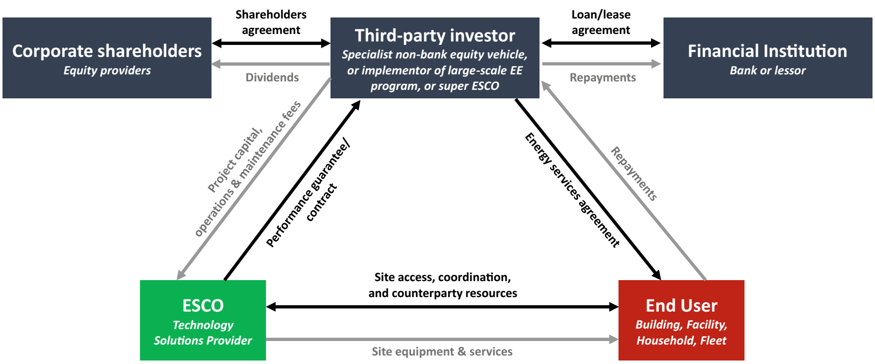

Fig. 2.3 Off-balance sheet transaction structure. *EE* energy efficiency, *ESCO* energy service company. *Source* Ablaza (2019a)

but rather could potentially serve as new intermediaries to deepen the reach of debt capital to energy efficiency project assets.

2.5.5 Large-Scale Government Programs

Governments can play significant roles in stimulating the growth of energy efficiency markets. Fiscal incentives such as income tax holidays and tax credits help improve project economics and create returns attractive enough for debt and/or equity funding by private investors. However, national or federal governments can also participate in off-balance sheet financing. The forced obsolescence of low-efficiency household and street lighting has been implemented in some countries. Customers turned over their existing lamps and lighting equipment to be replaced, usually for free, with more energy-efficient technologies. In such cases, returns are not realized by the investor (the government) through the typical energy savings cash flow stream. Rather, such activities promote energy efficiency on a national scale, ultimately benefiting industry players.

Having had early success in Europe, PPPs are starting to be considered for energy efficiency projects in Asia and the Pacific. A pioneer test case is the large-scale LED streetlighting project proposed for the State of Melaka in Malaysia. About 100,000 high-pressure sodium luminaires were targeted for energy-efficient LED luminaire replacements, which would effectively lower the overall cost of electricity and maintenance (Ablaza 2017). The Asian Development Bank (ADB) and the Melaka Green Technology Corporation (owned by the Melaka state government) entered into a collaborative agreement, which covered scoping, structuring of the transaction, and tendering. ADB's advisory support to this PPP transaction developed technical specifications, created the business case model, and conducted legal due diligence with respect to local regulations.

Programs are also developed at the municipal or local government level. In some markets, loans made for energy efficiency projects can be repaid over time via property taxes. On meeting qualification requirements, residential and commercial buildings receive funding from the state or local government to implement energy efficiency improvements, which could include hurricane proofing, seismic retrofitting, and renewable energy systems. Financing mechanics may vary based on national and local government regulations. One of the most successful property-based repayment schemes in the US is the Property-Assessed Clean Energy (PACE) program. In the US, investments are categorized in terms of commercial (C-PACE) and residential (R-PACE) (IEA 2018a), and cash flow streams from property tax payments are securitized for trading in financial markets (US DOE 2020).

A key feature that makes this program even more attractive is that repayment obligation is tied to the property rather than the home or building owner. As a result, even if the repayment stream spans decades, owners are still incentivized to pursue energy efficiency improvements. Should they sell the property in the future, the balance of the payment stream is transferred to the new owner. Altogether, the PACE program reduces energy expenses while increasing property values. As of this writing, 33 US states and the District of Columbia passed legislation enabling

PACE. Nineteen of these states plus the District of Columbia currently have operating PACE programs.

2.5.6 Utility-Led Demand-Side Management

Demand-side management (DSM) is a means for utilities to reduce energy costs on a large scale primarily through reducing consumption during peak hours. Utilities assess the electricity usage patterns of their customers and provide rebates to them to reshape their consumption behaviors. Flattening the load curve, combined with employing energy storage resources, helps avoid the higher per kilowatt hour generating costs from either peak power plants or peak prices resulting from imbalances caused by variable renewable energy sources such as solar and wind. Off-balance sheet investments may also be made by utilities through providing more energy-efficient technologies to customers to replace their existing equipment. On-bill recovery mechanisms combined with energy savings from shaved peak loads allow utilities to recoup and earn a return on their investment.

Emerging applications can also be seen in the smart grid, wherein customers can potentially provide utilities access to their smart (i.e., internet-connected) appliances and equipment. The assets can be remotely turned off or switched to low-consumption settings during peak hours, and customers are compensated with a share of the energy savings. Utility-led DSM effectively serves as a portfolio of small-scale energy efficiency projects with relatively lower capital intensity (depending on the type of DSM employed) and governed by a shared savings model.

Utility-led DSM can still be promoted in vertically integrated electricity markets, particularly because the economic and financial benefits of energy savings achieved at the level of the utility customers can directly flow up to the generation side of the utility business. Electricity markets that have restructured to unbundle generation from transmission and distribution, as well as accommodating retail competition and open access, now face challenges in crafting an energy efficiency financing channel role for distribution utilities.

2.6 Case Studies

2.6.1 Energy Efficiency Revolving Fund in Thailand

An energy efficiency revolving fund (EERF) was established in Thailand primarily to address financial barriers of energy efficiency projects and stimulate increased participation of commercial banks (Wang et al. 2013). The government's energy efficiency programs are managed by the Department of Alternative Energy Development and Efficiency (DEDE), an agency under the Ministry of Energy. DEDE manages the Energy Conservation Fund, which ultimately provides capital to the EERF for a 10-year period spread over five phases (UNIDO 2015). Between 2003 and 2012, $220 million was allocated for the EERF, with $60 million each for the first three phases, followed by $28 million and $12 million for the fourth and fifth phases, respectively.

A standard contract between DEDE and participating banks (PBs) facilitates disbursements that will be used by the latter to lend to clients for their energy efficiency projects. The EERF lends to PBs at a 0.5% interest rate to cover administrative costs and potential defaults (Energy Futures Australia 2005, Fig. 2.4). PBs, which then flow the funds to energy efficiency projects, are required to cap their lending rates at 4% per annum and their loan size at B50 million ($1.25 million) per project. Should projects require funding beyond B50 million, the commercial banks should provide the balance. From the six PBs at the start of the funding program, the EERF eventually signed agreements with 11 commercial banks (Grüning et al. 2012).

The target market of funding by the EERF comprises buildings, factories, ESCOs, and project developers (Grüning et al. 2012). Eligible facilities must meet at least one of the following requirements: (i) minimum installed electrical demand of 1,000 kW, (ii) minimum installed transformer capacity of 1,175 kV amperes, or (iii) minimum commercial energy consumption (including electricity and steam) of 20 million megajoules per year. These eligibility criteria were subsequently revised to broaden the fund's market as initial loan volumes were observed to be low (UNIDO 2015). As for building and/or factory project eligibility, the qualifying scope included, but was not limited, to efficient fuel combustion, energy loss reduction, energy waste recycling, peak shaving, power factor improvements,

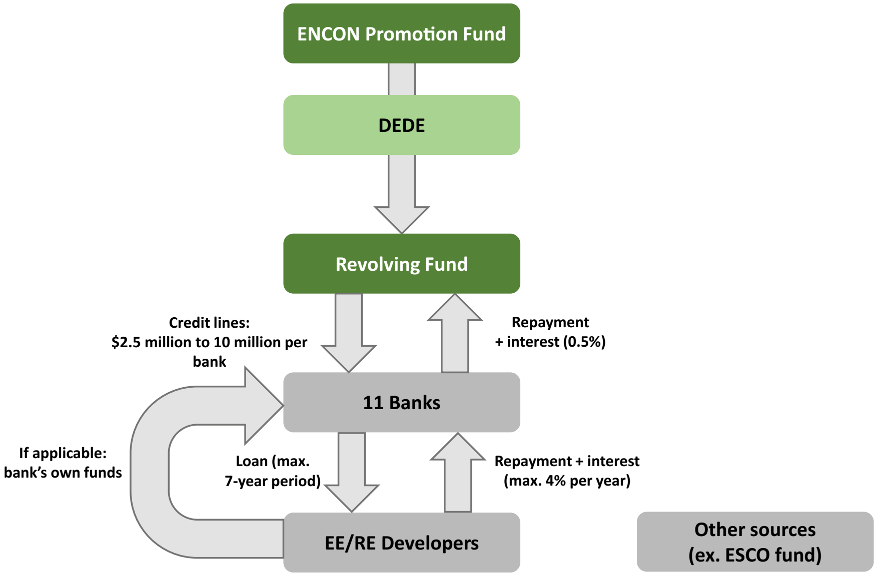

Fig. 2.4 Thailand EERF structure. *DEDE* Department of Energy Development and Efficiency *EE* energy efficiency, *EERF* Energy Efficiency Revolving Fund, *ESCO* energy service company, *RE* renewable energy. *Source* Grüning et al. (2012)

sunlight heat reduction, and efficient air conditioning (Energy Futures Australia 2005). Applicable uses of loan funds included the following:

- Equipment purchase cost and installation cost
- Engineering, design, and supervision costs
- Payables to ESCOs arising from a guaranteed savings model
- Operating and maintenance costs related to the equipment
- Transportation and demolition costs
- Import taxes, duties, and value-added taxes associated with any of the costs above.

While DEDE sets the policies and guidelines for the disbursement and use of the EERF's funds, the PBs, as the counterparties for loans made for energy efficiency projects, are ultimately responsible for implementing the guidelines and monitoring loans. Six months after fund disbursement to a PB's client, DEDE must receive a monitoring report analyzing the performance of the project. PBs must also submit supplementary monthly reports to DEDE to ensure that EERF funds are being held by PBs for no longer than 2 months. Performances of PBs under the program are measured based on nonbinding individual disbursement targets negotiated by each under the EERF.

From 2003 to 2010, the EERF funded 335 energy efficiency and renewable energy projects totaling $453 million in investment, with $210 million (or 46%) being sourced from EERF disbursements. Estimated energy savings up to 2009 were $154 million annually, resulting in an average payback period of 3 years (Wang et al. 2013). Beyond investment values, the success of the EERF was evident in how it reshaped stakeholder involvement in the energy efficiency sector. For commercial banks, mobilization of capital increased due to the foundational deal flow stimulated by the EERF at below-market financing rates. From merely matching the funds sourced from EERF disbursements, banks eventually took on more risk and provided more capital as they developed a better understanding of energy efficiency projects' technical aspect and business model. Also, as the EERF streamlined procedures and focused on achieving energy savings, the time it took to approve loans (and subsequently the time it took to begin implementing projects) was drastically shortened (EFA 2005). Through the EERF, implementation responsibilities were also decentralized away from the government, as banks took charge of processing loans and ensuring that guidelines set by DEDE were met.

Taking a closer look at Thailand's EERF experience, greater success could have been achieved if not for certain limitations of the program. For instance, the THB50million project size cap precluded larger-scale projects (EFA 2005) with correspondingly larger potential energy savings. PBs were also required, under the terms of the EERF, to assume all credit risk. Consequently, they used asset-based financing, which naturally filtered out small- and medium-sized businesses that lacked sufficient collateral (Wang et al. 2013). Finally, a budget allocation specific to the marketing of the EERF could have promoted awareness of the program and contributed to a larger and more diversified deal flow for PBs.

2.6.2 Industrial Energy Efficiency Landscape and Third-Party Financing in Singapore

The manufacturing sector accounts for more than half of Singapore's greenhouse gas emissions, and hence it has long been a target for cutting energy consumption. In 2016, the government announced its goal under the Climate Action Plan to improve the sector's energy efficiency at rates of 1%–2% yearly between 2020 and 2030, a rate that will be on par with that of leading developed countries such as Belgium and the Netherlands (Soh 2016). Recently, the Economic Development Board (EDB) and the National Environment Agency have stepped up their grants to better help industrial facilities to be more energy efficient and competitive. The funding support for the adoption of energy-efficient technologies under the EDB's Resource Efficiency Grant for Energy and the National Environment Agency's Energy Efficiency Fund will be increased from the existing cap of 30% to 50% of the qualifying costs—i.e., labor force, equipment or technology, and professional services costs (EDB 2018) (see Table 2.3 for more energy efficiency policies in Singapore's manufacturing sector).

Table 2.3 Energy efficiency policies in Singapore's manufacturing sector

Policy	Description
Mandatory Energy Management Practices under the Energy Conservation Act (ECA)	Enacted in 2012, the ECA serves to mandate energy efficiency requirements and energy management practices to promote energy conservation, improve energy efficiency, and reduce environmental impact, and to make consequential and related amendments to certain other written laws A. Mandatory energy management practices for existing industrial facilities B. Mandatory energy management practices for new industrial facilities and major expansions
Incentives and Grants: Energy Efficiency Fund (E2F)	Launched in 2017, through the provision of grants, E2F supports the energy efficiency efforts of companies in the industrial sector. It encourages owners and operators of facilities to: A. Integrate energy and resource efficiency improvements into their development plans early in the design stage B. Conduct a detailed energy assessment for their facilities to identify energy efficiency improvement opportunities C. Invest in energy-efficient equipment or technologies
Incentives and Grants: Singapore Certified Energy Manager (SCEM) Training Grant	The SCEM program caters to engineering professionals intending to develop a career as energy managers. It offers participants the chance to acquire technical skills and competencies for managing and tracking energy use within the organizations they serve

(continued)

Table 2.3 (continued)

Policy	Description
Incentives and Grants: Energy Efficiency Financing (EEF) Programme	The Singapore Economic Development Board (EDB)-piloted EEF program encourages owners and operators of existing industrial and manufacturing facilities to improve energy efficiency in their equipment and technologies (EDB 2018). Companies will be provided with upfront capital through a third-party financier to implement these projects
Resource Efficiency Grant for Energy (REG(E))	Introduced by the EDB, (REG(E)) will replace and build on the Productivity Grant for Energy Efficiency (PG(EE)). The aim of (REG(E)) is to better incentivize companies to achieve higher carbon abatement; the grants received by the companies will correspond to the amount of abatement achieved
Energy Efficiency National Partnership (EENP)	The National Environment Agency (NEA) launched the EENP program in 2010. The program develops learning network activities and provides energy efficiency-related sources, incentives, and recognition in order to support companies in their energy efficiency efforts

Source Authors' compilation (2020)

EDB Singapore made an effort to encourage financing for energy efficiency projects in industrial and manufacturing facilities by partnering with a commercial fund manager to pilot a third-party financing model that incorporates risk sharing (E2F Singapore 2017). Leveraging on loans from financial institutions, third-party fund managers provide companies with 100% of the upfront capital costs to finance the installation of energy-efficient technologies, systems, and equipment. At the same time, it subcontracts the design, installation, maintenance, measurement and verification services, and performance guarantee to qualified companies. In return, the companies pay for the investments from savings, based on a share of energy savings over an agreed contractual term (typically 5 to 10 years).

This third-party financing pilot scheme has reported limited success so far, with a low uptake of seven projects over 9 years. This is attributed to companies' concerns about the high transaction cost involved in third-party financing, large companies preferring to tap into internal funds or borrow from banks that offer low interest rates (large companies are capable of attaining bank loans because of their high creditworthiness), and most importantly, financial institutions associate third-party financing with high risk.

2.7 Conclusion and Recommendations

ESCO-based models could potentially accelerate capital mobilization toward energy efficiency projects. The injection of ESCOs as a third party into a typical project transaction between lending financial institutions and borrowing end users leads to an acceptable reallocation of risks. ESCOs have the technical competence to take on project risk, and the performance contracting structure removes the financial burden of energy efficiency infrastructure from the end user's balance sheet. However, the aggressive expansion of ESCOs' project pipelines is inhibited by financial and market frictions. Risk aversion of financial institutions toward energy efficiency limit ESCOs' sources of project financing. Furthermore, ESCOs, particularly in countries wherein the industry is young, need much improvement in their technical and contracting capabilities to facilitate aggressive growth. Below are several barrier-removal interventions for ESCOs:

- Shifting EE debt finance from traditional asset-based lending to energy savings-based lending and reduce creditworthiness requirements for ESCOs
- Reducing loan pricing of financial institutions by (i) sourcing wholesale or sub-commercial long-term funding, and (ii) rationalizing risk premiums through technical advisory support
- Extending long-term savings-based loans (with fixed, concessional pricing) to new super-ESCO entities that will serve as portfolio aggregator of commercially viable EE projects
- Creating new financial structures, vehicles, and products that would flow project equity and other forms of off-balance sheet capital
- Creating ESCO guarantee funds to help manage energy savings performance risk and customer credit risk
- Developing the monitoring & verification and performance contracting capabilities of the ESCO sector
- Developing industry-standard performance contract templates.

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Chapter 3
Review of Voluntary Agreements on Energy Efficiency: Promoting Energy Efficiency Financing in ASEAN Countries

Jeong Won Kim and Yang Liu

Abstract The Association of Southeast Asian Nations (ASEAN) countries need to consider more innovative, market-oriented approaches to accelerate energy efficiency improvement. Well-designed voluntary agreements help companies understand the importance and benefits of energy efficiency and engage in activities to improve industrial energy efficiency. Hence, they can contribute to overcoming some challenges that ASEAN countries face in promoting energy efficiency financing schemes and raising the effectiveness of the schemes. This study reviews how successful voluntary agreements in energy efficiency in five countries (People's Republic of China, Finland, Japan, the Netherlands, and the United Kingdom) achieved their targets in order to draw implications for designing future voluntary agreements in ASEAN countries. We find that three design elements: ambitious and realistic target setting, effectively enforceable incentives and penalties, and a strong monitoring and evaluation mechanism, are essential for well-functioning voluntary agreements. In addition to these elements, the unique conditions of each country must be considered, and transparency must be ensured to maximize the effectiveness of voluntary agreements.

Keywords Voluntary agreements · Energy efficiency · Energy efficiency financing · Energy-intensive industry · ASEAN

JEL Classification Q48 · H32

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3.1 Introduction

Market-based instruments refer to a set of policy frameworks specifying the outcome to be delivered by market actors by recreating their economic incentive structure, without prescribing the delivery mechanisms. These instruments, including taxes, subsidies, and cap-and-trade systems, have long been used in energy efficiency policies as essential complements to direct regulations. Despite their popularity and various advantages, market-based instruments still face criticism about some disadvantages. Top-down economic policy instruments, such as taxes and government grants and subsidies, may induce immediate compliance by companies, but will hardly lead to the continuous incentive for long-term behavioral change (Lindén and Carlsson-Kanyama 2002). Also, economic incentives from the government may cause moral hazard in corporate financing, particularly when they are in advance, unconditional, and nonrefundable. Some studies reported financial support from the government did not have a significant effect or negatively impacted on the innovation performance of companies (Hong et al. 2015; Simachev et al. 2015). Thus, it is important that companies strive to achieve the policy goal, such as improving industrial energy efficiency, to increase the effectiveness of market-based instruments.

Voluntary agreements can play a vital role in overcoming this challenge. A voluntary agreement refers to a contract between a public authority and a company or an industrial subsector to facilitate the participants' voluntary action based on their self-interest in achieving socially desirable outcomes encouraged by the government (Storey et al. 1999). Under a voluntary agreement on energy efficiency, the government and industrial participants usually negotiate and agree on energy-saving and greenhouse gas (GHG) emissions reduction targets, time schedules, action and technologies to achieve the targets, and supportive measures and penalties to ensure compliance (Fawkes et al. 2016; Rezessy and Bertoldi 2011; Tanaka 2011). Due to the higher efficiency and greater flexibility than traditional regulatory approaches and the ease of combining with other market-based instruments, voluntary agreements have been employed as new policy instruments to improve industrial energy efficiency and reduce energy-related GHG emissions in many countries since the 1990s. In many cases, joining voluntary agreement programs and meeting the targets stated in the agreements are preconditions for benefiting from energy efficiency financing schemes, such as subsidies and tax incentives, so that they can avoid inefficient government spending. The companies targeted by voluntary agreements in the past were mainly large energy end users or industrial subsectors, but recently, have been gradually extended to small and medium-sized enterprises (Rezessy and Bertoldi 2011).

The Association of Southeast Asian Nation (ASEAN) countries have experienced tremendous economic growth over the last 2 decades, and consequently are facing increasingly pressing energy and environmental challenges. The aggregated gross domestic product (GDP) of the ASEAN countries has increased almost fivefold from \$0.6 trillion in 2000 to \$3.0 trillion in 2018, with an average annual real GDP growth rate of 5.3% (ASEAN 2019). This growth rate is more than double that of the member countries of the Organisation for Economic Co-operation and Development (OECD), estimated at 2.02% over the same period (authors' estimate from OECD Statistics database). The accelerated growth has been coupled with a surge in energy demand, and the increasing trend is expected to continue. Indeed, the total final energy consumption in this region is projected to increase from 427 million tons of oil equivalent (Mtoe) in 2015 to 1,046 Mtoe in 2040 (ACE 2017), which will lead to an increase in CO_2 emissions from approximately 1.4 gigatons in 2018 to 2.4 gigatons in 2040 (IEA 2019).

Under these circumstances, improving energy efficiency is recognized as one of the most cost-effective solutions for addressing both energy security and climate change (ACE 2019a). For this, ASEAN countries have set up a collective energy efficiency target to reduce regionwide energy intensity to 20% by 2020 and 30% by 2025 based on the 2005 level (ACE 2015), alongside their individual national energy efficiency targets. Despite a steady decrease in collective energy intensity level, the ASEAN countries confront the daunting challenge of accelerating energy efficiency improvement. Especially, the fact that the pace of energy intensity reduction has slackened since the mid-2000s requires the ASEAN countries to consider more innovative, market-oriented approaches together with the regulatory instruments currently in place. The ASEAN countries are recently expanding efforts in developing more advanced energy efficiency financing models and attracting public and private investments. However, it is still unsure whether these financing schemes will result in a significant increase in industrial energy efficiency in the ASEAN countries due to the lack of rigorous monitoring and assessment systems, awareness of the importance of energy efficiency projects, and technical capacity of companies. Thus, the ASEAN countries need to consider expanding voluntary agreements to complement the energy efficiency financing schemes to prevent unwanted adverse effects of financial support, and raise awareness and capacity of companies.

While more countries are considering voluntary agreements as a policy option, particularly in the industrial energy efficiency field, the ASEAN countries have little experience and know-how to implement voluntary agreements. Further, an in-depth discussion on promoting voluntary agreements in the ASEAN countries is not common. This chapter aims to review the design issues of voluntary approaches successfully implemented in the People's Republic of China (PRC), Finland, Japan, the Netherlands, and the United Kingdom, and draws on lessons that are useful for charting a future voluntary agreement scheme for the ASEAN countries. In the five country cases, ambitious and realistic target setting, effectively enforceable incentives and penalties, and a strong monitoring and evaluation mechanism enabled their voluntary agreement schemes to produce satisfactory outcomes.

The remainder of this chapter is organized as follows. Section 3.2 describes the characteristics and working mechanism of voluntary agreements. Then, Sect. 3.3 gives an overview of trends in the energy intensity level of the ASEAN countries and introduces market-based instruments and voluntary agreements that have been implemented to improve industrial energy efficiency in the ASEAN countries.

Section 3.4 provides success factors of voluntary agreements based on the review of voluntary agreements in the five countries in terms of sector coverage; administrative framework; target setting; incentives and penalties; and monitoring, reporting, and evaluation. Finally, Sect. 3.5 summarizes the findings.

3.2 Voluntary Agreements Mechanism

3.2.1 Implementation Process

As the first step in a voluntary agreement, the government should target a selected group of end consumers as potential participants. The participants, in general, include individual companies or industrial subsector associations. One of the prominent features of voluntary agreements is that the implementation of this policy instrument is rooted in the "voluntary" action of businesses, which distinguishes it from traditional regulation. Individual companies have the freedom to either participate or not in the agreements (Cornelis 2019; Zhang et al. 2018a).

Once a company or an industrial subsector association decides to participate in a voluntary agreement, the government needs to negotiate with all the participants on the conditions of the agreement. In general, the agreement should describe energy-saving or GHG emissions reduction targets, the participants' duties (e.g., energy-saving measures to achieve the targets); benefits as compensation for compliance; and the mechanism for monitoring, reporting and evaluation. The negotiation process requires a horizontal relationship and continuous communication between the government and participants since they must reach a consensus on the contents of the agreement (Lindén and Carlsson-Kanyama 2002). Both individual companies and industry associations are eligible to join voluntary agreements. If an agreement is made between the government and an industry association, the targets at the subsector level should be fixed first, and then individual targets for each company member of the association are set accordingly (Rezessy and Bertoldi 2011).

Voluntary agreements typically cover 5–10 years. Unlike the command-and-control approach, legal punishment cannot be imposed on companies under voluntary agreements if they fail to meet the targets or fulfill their agreed duties. Thus, the failures are also handled in a way pre-agreed by both parties (Lindén and Carlsson-Kanyama 2002).

3.2.2 Advantages and Disadvantages of Voluntary Agreements

If the government can introduce new taxes or regulations with little political resistance, voluntary agreements may be the second-best option because the regulatory measures will force companies to adopt more energy-efficient technologies while phasing down inefficient facilities from the market (Lyon and Maxwell 2003). Nevertheless, voluntary agreements have some advantages in terms of flexibility and cost-effectiveness compared to traditional regulation and economic instruments (Zhang et al. 2018a, b).

First, voluntary agreements can overcome inefficiency caused by information asymmetry between the industry and the government. Given the heterogeneous nature of industrial facilities and technologies, it is almost impossible to set up differentiated objectives that suit the specific conditions of each company. Regulatory authorities often have poor knowledge of optimal technologies and the cost of employing them, so important factors such as the marginal cost of energy efficiency measures and specific challenges the company faces, cannot be taken into consideration (Menanteau 2005). Unlike regulations allowing public authorities to set uncompromisable targets and issue guidelines, voluntary agreements enable individual companies to establish their own plans and determine specific technologies and measures to achieve the agreed targets (Croci 2005; Zhang et al. 2018b). Such greater autonomy and flexibility in decision making can increase the level of interest in energy efficiency improvement among top executives of companies (Reinaud and Goldberg 2012). Having better knowledge of their current situation and available technologies, the companies can adopt the most cost-effective and suitable energy-efficient technologies.

Second, through information sharing among participants, voluntary agreements enable companies to save time and resources in collecting the information required to make corporate decisions (Croci 2005; Zhang et al. 2018b). Indeed, disseminating information and best practice is an essential function of voluntary agreements (Lindén and Carlsson-Kanyama 2002). In many voluntary agreements, the government organizes networking and training sessions to provide participating companies with the information and capabilities necessary for energy efficiency improvement. In particular, when voluntary agreements engage an industry association, companies are encouraged to share information with other peers in order to meet the subsector-wide targets (Croci 2005; Zhang et al. 2018b). Given that searching for and analyzing information is a time-consuming and costly process, a company is mostly unable to gain complete information. Thus, voluntary agreements help the participating companies to build on their technical capacity through this collective learning process in a relatively short time and at a lower cost.

Thirdly, voluntary agreements can also lower administrative costs. During the negotiation and implementation stage, constructive dialogues among key stakeholders are usually maintained through various channels, including direct communication, educational and training sessions, and network meetings (Lindén and Carlsson-Kanyama 2002). The negotiation process may require the government and companies to spend enough time and effort to conclude a final agreement. However, it is still a faster and less burdensome process than enforcing new regulations by law (Tractbel ENGIE 2018). More importantly, proactive communication contributes to building trust between the parties, forming a consensus, and consequently, reducing monitoring and enforcement costs (Croci 2005).

On the negative side, one of the major disadvantages of voluntary agreements is associated with free riding. This situation may happen when the agreement engages an industry association. In this case, some individual companies may benefit from free riding the efforts of other companies in achieving the targets set at the subsector level (Menanteau 2005; Zhang et al. 2018b). These free riders will enjoy the reputation generated by the program while contributing little to meeting the given target (Storey et al. 1999). Another risk of voluntary agreements is that pre-agreed targets may not be ambitious enough, in some cases even below the business-as-usual level. Since stricter energy efficiency targets may have significant implications for operation and maintenance costs, companies usually have an incentive to lobby the government to set targets lower than the optimal level that the voluntary agreement can bring about to society (Croci 2005; Zhang et al. 2018b). To mitigate these risks, many countries opt to establish a penalty mechanism to discourage noncompliance, introduce third-party participation, and base target setting on the energy audit.

3.2.3 Company-Level Motivation to Participate in Voluntary Agreements

Commitment to voluntary agreements incurs costs for companies. Whereas companies have the discretion as to whether to participate in voluntary agreements, they have to fulfill their duties, at their own expense, to meet the agreed targets once they enter into an agreement. Therefore, companies will decide to participate only if they anticipate that the potential benefits of doing so can outweigh the costs. In many cases, rewards that the government promises to the participating companies are strong drivers for companies. For example, companies may engage an energy efficiency target in exchange for support from the government, including technical and financial assistance (Croci 2005; Rezessy and Bertoldi 2011).

On the other hand, companies may participate in voluntary agreements to enhance their reputation for societal responsibility through energy saving and environmental protection (Croci 2005; Zhang et al. 2018b). Good environmental standing may help companies shore up their brand image and serve as a differential factor in marketing as consumers are increasingly aware of energy and environmental issues. Furthermore, as more and more companies choose to participate in a voluntary agreement, nonparticipants will become an outlier, and consequently increase the opportunity cost of nonparticipation (Thollander et al. 2013).

Lastly, some voluntary agreements have been particularly successful thanks to an implicit threat of putting into place a new binding regulation or tax in case the targets cannot be achieved (Tanaka 2011). In other words, companies will consider adopting voluntary agreements to avoid stricter regulations or taxation that the government would have introduced otherwise (Croci 2005).

3.3 Voluntary Agreements and Energy Efficiency in ASEAN Countries

3.3.1 Energy Efficiency of ASEAN Countries

The rapid economic growth of the ASEAN countries, coupled with a growing population and industrialization, has increased energy demand in this region. Between 2000 and 2017, the total final energy consumption in the ASEAN countries increased approximately 1.8 times from 274 to 486 Mtoe. Notably, the industrial sector emerged as the largest end user in 2017 (150 Mtoe), while being the second-largest energy consumer in 2000 (76 Mtoe) (IEA 2019). Furthermore, the *5th ASEAN Energy Outlook* (ACE 2017) expects the total final energy consumption in this region to grow 2.4 times from 427 Mtoe in 2015 to 1,046 Mtoe in 2040 under a business-as-usual scenario, where the current energy demand patterns are locked in.

Such trends of a sharp increase in energy consumption have prompted the ASEAN countries to face the dual challenge of mitigating GHG emissions while meeting the growing energy demand. To deal with these challenges, the ASEAN countries have identified energy efficiency and conservation as a cost-effective priority strategy and implemented various policy measures to improve energy efficiency (ACE 2019b).

As shown in Fig. 3.1, the collective energy intensity of the ASEAN countries displayed descending trends between 1990 and 2015 from 7.24 megajoules (MJ)/$ to 4.28 MJ/$. As of 2015, the energy intensity of the ASEAN countries was lower

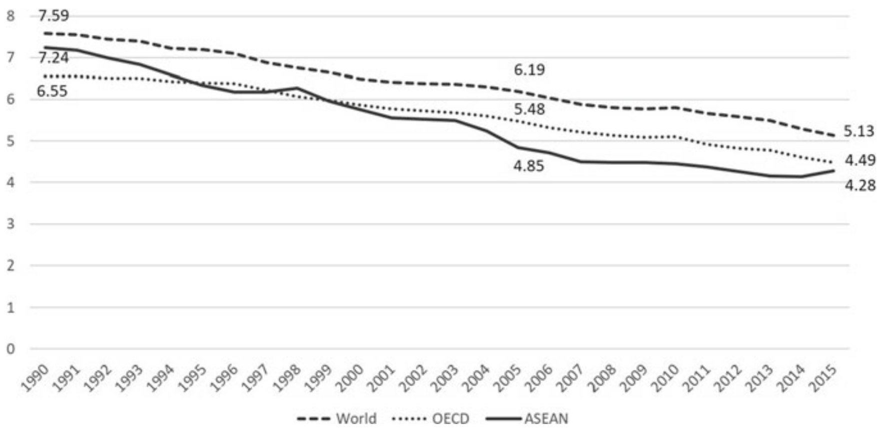

Fig. 3.1 Energy intensity of the World, OECD, and ASEAN countries, 1990–2015 (MJ/$2011 PPP GDP). *ASEAN* Association of Southeast Asian Nations, *GDP* gross domestic product, *MJ* megajoule, *OECD* Organisation for Economic Co-operation and Development, *PPP* purchasing power parity. *Source* World Bank Open Data. https://data.worldbank.org/ (accessed March 2020)

than the global average level (5.13 MJ/$) and even performed better than OECD member countries (4.49 MJ/$). Despite the remarkable improvement in energy efficiency in the 1990s and early 2000s, the progress has slowed since the mid-2000s. While the energy intensity in the world and OECD countries decreased by 17.1% and 18.2% respectively between 2005 and 2015, that of the ASEAN countries decreased by only 11.7% from 4.85 MJ/$ to 4.28 MJ/$. It is noted that during the same period, the PRC improved its energy intensity by 34.9%. Besides, energy intensity in individual states varies greatly among the ASEAN countries (Table 3.1). While Singapore, Myanmar, the Philippines, and Indonesia have shown significant improvement in energy intensity over the last decade, Viet Nam, Cambodia, Thailand and the Lao People's Democratic Republic (Lao PDR) still have relatively high energy intensity. Moreover, the energy intensity in 2015 in Brunei Darussalam, Cambodia, and the Lao PDR instead increased compared to the 2005 level.

Therefore, the ASEAN countries need to make more effort to increase their energy efficiency and promote energy savings. In fact, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025 states that the ASEAN countries will commit to reducing their collective energy intensity to 20% by 2020 and to 30% by 2025 based on the 2005 level (ACE 2015). In addition to this regional target, each country has set its own energy efficiency targets.

Table 3.1 Energy intensity of ASEAN countries (MJ/$2011 PPP GDP)

Country	2005	2008	2011	2013	2014	2015	Improvement (%)
Brunei Darussalam	3.39	5.28	5.54	4.39	4.75	3.65	−7.7
Cambodia	5.50	4.29	6.01	5.60	5.59	5.77	−4.8
Indonesia	4.86	4.25	3.94	3.75	3.68	3.53	27.5
Lao PDR	4.38	3.32	2.71	2.50	2.30	5.17	−18.1
Malaysia	5.77	5.65	5.13	5.33	5.13	4.68	18.9
Myanmar	5.68	4.13	3.04	3.03	3.13	3.12	45.0
Philippines	3.95	3.48	3.13	3.02	3.03	3.12	20.9
Singapore	3.42	3.23	2.83	2.62	2.48	2.39	30.0
Thailand	5.50	5.33	5.39	5.65	5.56	5.41	1.5
Viet Nam	6.02	5.86	5.97	5.62	5.75	5.94	1.2

ASEAN Association of Southeast Asian Nations, *GDP* gross domestic product, *Lao PDR* Lao People's Democratic Republic, *MJ* megajoule, *PPP* purchasing power parity. *Source* World Bank Open Data. https://data.worldbank.org/ (accessed March 2020)

3.3.2 Voluntary Agreements and Other Market-Based Instruments to Improve Industrial Energy Efficiency of ASEAN Countries

Most ASEAN countries have established their national plans and formed a legal framework for energy efficiency improvement. The ASEAN countries still rely heavily on traditional energy efficiency policies. For instance, the most common policy instruments in ASEAN consist of standards and labeling, mandatory energy audit and management, and capacity building. However, they are adopting more advanced market-based economic and fiscal instruments and voluntary models. Table 3.2 summarizes key market-based and voluntary policy measures aimed at increasing the industrial energy efficiency of each country.

Table 3.2 Key market-based and voluntary measures for industrial energy efficiency Improvement

Country	Category	Key policy measures
Brunei Darussalam	Market-based	• Electricity tariff reform
	Voluntary	–
Cambodia	Market-based	• Tax incentives for energy services companies (ESCOs) and companies interested in implementing energy efficiency projects
	Voluntary	–
Indonesia	Market-based	• Financing (e.g., loans, grants, insurance) for energy efficiency projects • Tax incentives for components and raw materials for energy efficiency appliances • Energy-saving performance contracts
	Voluntary	–
Lao PDR	Market-based	• Financing (e.g., grants) for energy efficiency projects • Tax incentives (exemption from export duty, discount on personal income tax for expatriate employees, etc.) for energy efficiency investments
	Voluntary	–
Malaysia	Market-based	• Financing (e.g., loans, grants, guarantees) for energy audit and energy efficiency projects: GTFS, EACG • Tax incentives (waiver of import duty and sales tax) for energy-saving equipment • Energy performance contracting fund for ESCOs
	Voluntary	–
Myanmar	Market-based	• Financing (e.g., loans, subsidies, guarantees) for energy efficiency projects: National Energy Efficiency and Conservation Fund • Tax incentives for investment in energy efficiency technologies and import of energy-efficient appliances
	Voluntary	–

(continued)

Table 3.2 (continued)

Country	Category	Key policy measures
Philippines	Market-based	• Financing (e.g., grants) for energy efficiency projects
	Voluntary	• Voluntary partnership with the business sector
Singapore	Market-based	• Financing (e.g., loans, grants, insurance) for energy efficiency projects: E2F, EEF (SDCL Loan) • Tax: Tax incentives (additional investment allowance against taxable income) for energy efficiency investment, Carbon tax on large emitters of GHGs
	Voluntary	• Voluntary partnership between government and companies: EENP
Thailand	Market-based	• Financing (e.g., loans, equity, grants, subsidies, guarantees, joint venture) for energy efficiency projects and ESCOs: ENCON Fund, EERF • Tax incentives (discount on VAT)
	Voluntary	• Voluntary agreements to save energy between public agencies and business associations and large-scale business
Viet Nam	Market-based	• Financing (e.g., loans, equity, grants, guarantees) for energy efficiency projects: VEPF • Tax incentives
	Voluntary	• Pilot voluntary agreements between government and companies

E2F Energy Efficiency Fund, *EACG* Energy Audit Conditional Grant, *EEF* Energy Efficiency Financing, *EENP* Energy Efficiency National Partnership, *ENCON* Energy Conservation Promotion Fund, *GHG* greenhouse gas, *GTFS* Green Technology Financing Scheme, *SDCL* Sustainable Development Capital LLP, *VAT* value-added tax, *VEPF* Vietnam Environment Protection Fund. *Source* Authors' summary based on ACE (2019a, b)

While voluntary agreements are one of the most common instruments for improving energy efficiency in many other industrialized countries in Europe and East Asia, no other ASEAN country except Singapore has formally implemented valid voluntary agreements. However, it is important to note the recent actions taken by the ASEAN countries to introduce and pilot voluntary agreements.

In Singapore, the National Environment Agency launched an industry-focused Energy Efficiency National Partnership (EENP) program in April 2010. This is a voluntary partnership program for companies interested in becoming more energy efficient to increase their long-term business competitiveness and minimize their carbon footprint. It comprises three subprograms: Energy Management System, EENP Learning Network, and EENP National Recognition Scheme. Through these programs, the EENP helps partner companies to save their energy consumption by providing relevant information by organizing workshops and training sessions, incentives and recognition. As of February 2020, the EENP had established partnerships with 291 companies.

The Philippines has designated voluntary agreements as a subprogram of the National Energy Efficiency and Conservation Program. The Ministry of Energy establishes partnerships with the private business sector. Under these partnerships, the government disseminates information about available technologies and relevant programs, provides energy audit services, and holds seminars. The companies carry out their own energy efficiency and conservation measures and monitor their energy consumption.

Viet Nam initiated a pilot voluntary agreement program on energy efficiency and saving in December 2016. Agreements were signed by the Ministry of Industry and Trade and seven companies—Ricoh Imaging Products Viet Nam, Annora Viet Nam Footwear, Vinh Hue Paper, Colusa-Miliket Foodstuff, Dong Xuan Knitting, Saigon Milk Factory of Vinamilk, and Viet Nam Food. The main objective of this program is to promote active energy saving in the industry sector by supporting their efforts to increase energy efficiency and reduce production costs. These seven companies are eligible to receive the government's financial support to cover 100% of their first energy audit. The government announced that the program would be scaled-up to a national level after the completion and evaluation of the pilot program.

In addition, according to the Thailand 20-Year Energy Efficiency Development Plan (2011–2030), Thailand will execute voluntary agreements as a measure for energy conservation promotion and support. The agreement is made between the public agency and the industrial sector, particularly industry associations and large companies. The Indonesian government has also communicated with energy-intensive industries including fertilizer, cement, pulp, and steel industries (Kementerian ESDM RI and ECN 2016).

For financial incentives, many countries have been using tax incentives and grants from the government. Some countries, such as Brunei Darussalam, Cambodia, Myanmar, the Lao PDR, and the Philippines are implementing no or only a few energy efficiency financing schemes. On the contrary, Malaysia, Singapore, and Thailand have adopted more market-based financing mechanisms, including bank loans and risk-sharing schemes.

Thailand is one of the regional leaders in energy efficiency initiatives and financing. The Thai government established the Energy Conservation Promotion Fund (ENCON Fund) in 1992 to promote energy efficiency projects. With the revenue from the taxes on petroleum products, the ENCON Fund not only directly provides loans and venture capital to energy efficiency projects including energy audits, capacity building and research and development, but also supports other financing schemes, such as the Energy Efficiency Revolving Fund (EERF) and the Energy Service Company (ESCO) Fund (ACE 2019b). The EERF, established in 2003, extends credit lines to participating banks at low interest rates to stimulate bank lending for energy efficiency projects. It aims at boosting large-scale energy efficiency investments by enhancing the capacity of local banks, such as developing streamlined procedures for project appraisal and loan disbursement, and mobilizing commercial investments (Wang et al. 2013).

Singapore also has a variety of energy efficiency financing schemes. The Energy Efficiency Fund (E2F), launched in 2017, supports the efforts of companies and industrial facilities to improve energy efficiency through the provision of grants. It focuses on resource-efficient design of new facilities and major expansions, energy assessment of existing facilities, adoption of energy-efficient equipment technologies, and implementation of an energy management information system. In addition, Singapore's Economic Development Board) partnered with Sustainable Development Capital LLP, and piloted the Energy Efficiency Financing program, which is a third-party financing model incorporating loans and risk sharing. Under this program, the third-party financier, Sustainable Development Capital LLP, provides companies with up to 100% of the upfront costs to implement energy efficiency projects, such as the introduction of energy-efficient technologies, systems, and equipment. In return, the companies pay for the investments from savings, based on a share of energy savings for an agreed contractual term.

In Malaysia, the Green Technology Financing Scheme was launched in 2010 to encourage the development and adoption of green technologies through a loan guarantee scheme that offers a more preferable interest rate than commercial banks. The government also established the Energy Audit Conditional Grant scheme in 2015 to assist in the reduction of energy consumption and GHG emissions from the industrial sector. This grant program supports energy audit and capacity building activities of large energy consumers (ACE 2019b).

3.3.3 Need for Voluntary Agreements to Overcome Challenges for Energy Efficiency Financing

Although various energy efficiency financing schemes are being developed in the ASEAN countries, some existing obstacles make the active implementation of those schemes and continuous improvement of energy efficiency still difficult. Several challenges for energy efficiency financing in the ASEAN countries, including low energy prices, limited institutional capacity, and weak capital markets, have been pointed out (ACE 2019a, b). However, the most fundamental and common problems are a lack of awareness of the importance of energy efficiency and the limited capacity of companies and financial institutions in developing and assessing energy efficiency projects.

First, limited awareness of companies leads to little interest in investing in energy efficiency projects. In the ASEAN countries, many companies still see energy efficiency projects as an additional cost factor rather than a commercially viable investment opportunity (ACE 2019b). Further, for companies, the low price of energy sometimes reduces the importance of implementing energy efficiency projects. Second, the limited capacity of companies and financial institutions including local banks also hinders the effective implementation of energy efficiency financing. For companies to benefit from energy efficiency financing programs, they have to apply for funding with innovative energy efficiency projects and financial institutions assess the eligibility of their projects. However, many companies and banks in the ASEAN countries have difficulty in developing and evaluating energy efficiency projects due to their limited experience with and superficial understanding of energy efficiency technologies. Consequently, financial institutions that have limited technical knowledge tend to be more open to providing financing for renewable energy projects than energy efficiency projects (ACE 2019b).

Voluntary agreements can play a critical role in raising the awareness and capacity of companies and engaging them with the materialization of multiple energy efficiency benefits. Multiple rounds of negotiation between the government and companies and collective learning processes among participating companies help companies recognize that energy efficiency projects would bring more profits to them and build their technical capacity in a relatively short time and at a lower cost. Furthermore, voluntary agreements can minimize side effects of financial support that may be produced in the future, including the moral hazard of companies based on information asymmetry. However, most of the voluntary agreements in place in the ASEAN countries are still at a nascent stage compared to those in other more developed economies. Also, as voluntary agreements have not been mainstreamed in the energy efficiency landscape, the number of participants is limited. Thus, the ASEAN countries need to improve the design of current voluntary agreement schemes as well as expanding them to increase the effectiveness of the voluntary agreements, and consequently, promote energy efficiency financing.

3.4 Lessons from Successful Voluntary Agreements

3.4.1 Selected Voluntary Agreements

Since the Netherlands introduced voluntary agreements in the energy efficiency field for the first time in 1991 (Cornelis 2019), they have been widely used for the industrial sector to meet specific energy efficiency and energy-saving targets. Significant environmental and economic benefits have been produced through these voluntary agreements. Drawing on lessons on how these voluntary agreements have achieved their targets can provide useful guidance for the ASEAN countries to design future voluntary agreements. The successful voluntary agreements examined in this chapter include:

- Top-10,000 Energy-Consuming Enterprises Program in the PRC (former Top-1,000 Energy-Consuming Enterprises Program): This is the most representative industrial program and sets company-level energy performance improvement targets in the PRC (Zhao et al. 2016). It also provides lessons on the setting of mandatory targets and imposing clear penalties for failure. The program was launched in 2005 as one of the key programs aimed at achieving the PRC's energy efficiency target of reducing energy consumption per unit of GDP by 20% below 2005 levels by 2010. The program aims to strengthen the energy management of the largest energy-intensive companies in the PRC. The targeted companies expanded from 1,000 companies to 10,000 companies in the 12th Five-Year Plan starting from 2010.

- Energy Efficiency Agreement for the Industrial Sector in Finland: The program was launched in 1997 as a key policy tool to fulfill European Union energy efficiency obligations set for Finland. The program has made satisfactory progress in all areas (Gynther and Suomi 2017). In particular, it provides lessons on establishing a proper monitoring and evaluation system, as well as communicating results to motivate further improvement.
- Keidanren Voluntary Action Plan on the Environment in Japan: The program was launched by the Nippon Keidanren (Japan Business Federation) in 1996 to contribute to meeting Japan's CO_2 reduction target under the Kyoto Protocol, and currently, has the goal of halving GHG emissions by 2050. It has achieved the targets successfully (Thollander et al. 2015). The success factors consist of setting robust targets consistent with the government's long-term projects and maintaining transparency and credibility.
- Long-Term Agreements on Energy Efficiency (LTA/LEE) in the Netherlands: The program is often known as the best practice in Europe and for including exemplary voluntary agreements (Abdelaziz et al. 2011; Cornelis 2019) and thus provides lessons for the monitoring of results and the provision of incentives. The LTA program aims to increase energy efficiency and encourage the use of renewable energy in the industry, agriculture and service sectors. The program was initiated in 1992, with the third phase starting from 2008. From the third phase, the agreements were separated into the LTA dedicated to companies not participating in the EU Emissions Trading System and the LEE for companies participating in the system.
- Climate Change Agreement (CCA) in the United Kingdom: The program was initiated in 2001 as part of the Climate Change Levy (CCL) package. Under this scheme, companies can get a discount on the CCL if they meet agreed carbon reduction targets. It has been effective at improving energy efficiency and raising awareness (Li et al. 2018) and provides lessons on how to implement a "stick-and-carrot" approach.

The key achievements of the above five voluntary agreements in the PRC, Finland, Japan, the Netherlands, and the UK, are summarized in Table 3.3.

Table 3.3 Key achievements of selected voluntary agreements

Country	Achievement in energy savings
People's Republic of China	• 150 Mtce reduction between 2005 and 2010 (50 Mtce more than the target) • 309 Mtce reduction between 2011 and 2014 (20% more than the target of 250 Mtce)
Finland	• 9,897 GWh reduction by the end of 2016 • In the energy-intensive industries, the cumulative savings in 2016 accounted for 8.3% of the sectoral total final energy consumption
Japan	• The uniform target in the industry sector (8.6% reduction in CO_2 emissions from 2008 to 2012 compared to 1990 level) was overachieved by 12.2%. Keidanren concluded that efficiency improvement was the vital driving force to meet the target
Netherlands	• LTA 1 and 2: 1.8–2.0%/year reductions between 1992 and 2008 • LTA 3 (non-ETS industry): 1.8%/year reductions between 2008 and 2016 • LEE (ETS industry to consume more than 0.5 PJ/year): 1.2%/year reductions between 2008 and 2016 • Cumulative savings: 63.4 PJ in 2016
United Kingdom	• 10.5 Mtce/year in CCA TP5, 4.9 Mtce/year in CCA2 TP2 (against baseline year emissions) • 82% of sectors and 53% of target units met their target in CCA2 TP2 (2015–2016)

CCA Climate Change Agreement, *ETS* emissions trading system, *GWh* gigawatt hour, *LTA* Long-Term Agreement, *Mtce* metric tonnes of carbon equivalent, *PJ* petajoule, *TP* target period. *Source* Authors' summary based on Cornelis (2019), Environment Agency (2017), Fawkes et al. (2016), Gynther and Suomi (2017), NDRC (2015), Thollander et al. (2015), Veum (2018)

3.4.2 Comparison of Design Elements

Sector Coverage

Voluntary agreements may vary significantly across the sectors they cover (Table 3.4). The main target of voluntary agreements has been large energy-intensive companies in the industry sector since the late 1990s, but today, an increasing number of countries are expanding voluntary agreements to non-energy intensive companies and other sectors as well (Rezessy and Bertoldi 2011). For example, the services sector including the public and commercial sector (the PRC, Finland, the Netherlands, the UK), the agriculture sector (Finland, the Netherlands, the UK) and the transport sector (the PRC, Finland, Japan, the Netherlands, the UK) have become the new target sectors of voluntary agreements. Finland, the Netherlands, and the UK are the countries that have the most comprehensive sectoral coverage.

Table 3.4 Sector coverage of selected voluntary agreements

Country	Number of participating companies	Industry (large)	Industry (SMEs)	Public	Commercial	Transport	Agriculture
People's Republic of China	17,000	V (energy consumption > 10,000 tce/year)		V	V	V	
Finland	460 (85% of industrial energy use)	V	V	V	V	V	V
Japan	114 associations (80% of industrial CO_2 emissions)	V	V		V	V	
Netherlands	1,100 (>80% of industrial energy use)	V (energy consumption > 0.5 PJ/year)	V (energy consumption < 0.5 PJ/year	V	V	V	V
United Kingdom	3,184	V	V	V	V	V	V

PJ petajoule, *SMEs* small and medium-sized enterprises, *tce* tonnes of carbon equivalent. *Source* Authors' summary based on Abeelen, Harmsen, and Worrell (2016), EC (2017), Environment Agency (2017), Fawkes et al. (2016), Gynther and Suomi (2017), Li et al. (2018), Wakabayashi and Arimura (2016)

Furthermore, the target group of voluntary agreements must cover a significant part of an industry, in terms of the number of companies or share of total industrial energy consumption, to ensure a substantial impact (Rezessy and Bertoldi 2011). For example, in Finland, Japan, and the Netherlands, the participating companies' energy consumption accounts for 80–85% of the total industrial energy consumption in these countries.

Target Setting

In most cases, the targets of voluntary agreements are quantifiable, but comparing the target level between countries is difficult because of the differences in timelines, calculation methods, and units. Thus, such a comparison focuses on the structure and process of target setting, rather than the absolute level of the targets. Table 3.5 summarizes the key elements of the target setting in selected agreements.

The PRC, Finland, and the UK have both sector-level and individual company-level agreements. When voluntary agreements are signed with industry associations, the targets of individual companies are set within the sectoral targets, and later, individual companies report their achievements to the associations to which they belong (Rezessy and Bertoldi 2011). Regardless of whether they are sectoral targets or company-level targets, the targets in the voluntary agreements are usually determined through negotiation between the government and the target group. The UK's CCA between the former Department of Energy and Climate Change (now the Department for Business Energy and Industrial Strategy) and the industry associations illustrates the typical target-setting process of voluntary

Table 3.5 Target setting of selected voluntary agreements

Country	Expression	Sector-level target	Company-level target	Mandatory	Process
People's Republic of China	Energy intensity reduction (tce)	V (local level)	V	V (Companies are allowed to aim for more ambitious, voluntary standards)	Local provinces propose their total energy-saving targets estimated based on energy-saving potentials of local companies reported by each company. After the review of the central government, final targets are determined through the negotiation between provincial and central governments
Finland	Energy savings (GWh/year)	V	V		The government and the Confederation of Finnish Industries sign the Framework Agreement. Then, sector-specific action plans, including sectoral targets, are established
Japan	Various (each industry can select)	V	n/a		The government does not directly engage in negotiations to set the targets. Each industry association discusses the sector-wide target based on the investigation of member companies to assess their feasibility to meet the target
Netherlands	Relative energy savings	n/a	V		Participating companies submit an Energy Efficiency Plan every four years containing the qualitative and quantitative targets
United Kingdom	Various (majority: relative energy savings)	V	V		The industry association offers a sector-wide target to the government. Then, they agreed on the sector targets through negotiation

GWh gigawatt hour, *tce* tonnes of carbon equivalent. *Source* Authors' summary based on Abeelen, Harmsen, and Worrell (2016), EC (2017), Environment Agency (2017), Gynther and Suomi (2017), Li et al. (2018), Thollander et al. (2015), Veum (2018), Wakabayashi and Arimura (2016), Zhao et al. (2016)

agreements. The government collected information about the energy efficiency potential of energy-intensive industries and identified the 10 largest energy-consuming sectors. Then, individual companies in the sector assessed their potential to improve energy efficiency and reported the targets that they can achieve to their trade associations. After that, each industrial sector offered collective sectoral targets to the government, and the final targets for the next 2 years were determined through negotiations between the government and the trade associations

(Abdelaziz et al. 2011). The targets varied widely, ranging from 25% for the laundry industry to 2.8% for the aluminum industry.

Although the agreements are voluntary, energy-saving targets may be regarded as binding in some countries. the PRC's Top-10,000 Energy-Consuming Enterprises Program set up mandatory company-level targets, in terms of the amount of energy saved. Moreover, the program also encouraged companies to set voluntarily more ambitious energy intensity standards beyond the mandatory target. On the other hand, the UK's CCA makes the target virtually mandatory by connecting the achievement of the targets with the CCL. Given that noncompliance leads to the payment of a full tax rate under the CCL, participating companies have been forced to achieve their targets even though the targets themselves are not mandatory (Li et al. 2018).

Incentives and Penalties

Tax exemption and cost recovery through the provision of subsidies have been mainly used to incentivize companies' compliance (the PRC, Finland, the Netherlands, the UK). For nonfinancial incentives, the PRC and Japan have formed a network among the participating companies. Creating a network and holding regular network meetings are useful for catalyzing and expanding the efforts of companies to achieve energy efficiency improvements by providing relevant information to assist with corporate decision-making and reduce transaction costs. Meanwhile, penalties included in the voluntary agreements vary across the country (Table 3.6).

Table 3.6 Incentives and penalties of selected voluntary agreements

Country	Incentive		Non-compliance penalty
	Financial	Non-financial	
People's Republic of China	• Financial support for energy-saving projects (CNY200/ tce/year)	• Networking • Training/ consulting	• Notice of criticism • Mandatory energy audits adjustment/ retrofit • Approval of capital projects or additional land use requests may be suspended. (company, local governments)
Finland	• Subsidies (€10,000–€500,000)	• Training/ consulting	• Repayment of subsidies
Japan		• Public information disclosure • Networking	• Public information disclosure
Netherlands	• Tax rebate • Subsidies	• Training/ consulting	• Tightened environmental license
United Kingdom	• Tax (CCL) rebate		• Discontinuation of tax rebate • Financial penalties for minor infringements

CCL climate change levy, *tce* tonnes of carbon equivalent. *Source* Authors' summary based on Abdelaziz, Saidur, and Mekhilef (2011), Fawkes et al. (2016), Li et al. (2018), Veum (2018), Wakabayashi and Arimura (2016), Zhao et al. (2016)

The UK's CCA is renowned for its stick-and-carrot approach, as part of the coordinated action under the CCL (Li et al. 2018). Even though participation in a CCA is entirely voluntary, the government conditions companies' compliance to manifest incentives and penalties within the agreement. The CCA allows the participants to receive a rebate on the CCL of up to 90% for electricity and 65% for gas and other fuels if they fulfill their obligations (Cornelis 2019; Environment Agency 2017). By contrast, if the energy-saving targets are not achieved over a 2-year period, the discount will not be renewed for the next 2-year target period. Companies that still intend to claim the CCL discount despite their failure to meet the targets have two alternatives: either using banked surpluses accrued through over-achievement during the previous target periods or paying a "buy-out fee" to the government (Environment Agency 2017; Li et al. 2018). The CCA also sanctions financial penalties for minor infringements such as missing the reporting deadlines or reporting inaccurate data.

The PRC's Top-10,000 Energy-Consuming Enterprises Program has implemented the stiffest penalties among the five countries. A "notice of criticism" is issued to companies failing to achieve their targets. The penalties for these companies include suspension of approval of requests for capital financing or industrial land use and other economic sanctions. Not only the companies but also local government officials are subject to the penalties. If their jurisdictions do not meet the targets, the relevant government officials will be disqualified from promotion and honorary rewards or titles (Fawkes et al. 2016).

Monitoring, Reporting, and Evaluation

Table 3.7 provides an overview of the stakeholders in charge of monitoring energy savings and methods for evaluation and verification. Each participating company reports its annual performance to the evaluation organization (mostly the government agency). The evaluation organization reviews the reports and confirms the results. In addition, the voluntary agreements in Finland and the UK have developed an online platform for data collection and tracking of the implementation status. This web-based reporting system can reduce administration costs, and improve processing efficiency and transparency (ATEE 2017).

The five countries show differences in the methods used to verify the results reported by the companies. First, the UK confirms the results based on both desk-based reviews of reports submitted and on-site inspections. The target companies for on-site inspections are selected randomly or decided using a risk-based approach (Li et al. 2018). Second, the Netherlands and Japan do not conduct onsite inspections, but they require companies to comply with their targets by hiring external consultants or disclosing the results to the public. The external consultants check all the monitoring reports submitted to the Netherlands Enterprise Agency to confirm their completeness and correctness. This is done by comparing the reported data about energy use and production and projected data (Abeelen, Harmsen, and Worrell 2016). On the other hand, Japan's Keidanren not only shared the collected

Table 3.7 Monitoring and evaluation of selected voluntary agreements

Country	Monitoring organization	Verification (evaluation) organization	Verification methods
People's Republic of China	Company	Local energy-saving offices	• Desk-based review
Finland	Company	Motiva (contractor)	• Web-based monitoring system
Japan	Company, industry association	Industry association, Keidanren	• The collected information is shared among the member companies and made public
Netherlands	Company	Netherlands Enterprises Agency	• Desk-based review by external consultants
United Kingdom	Company	Department for Business Energy and Industrial Strategy, Environment Agency	• Electronic register • Audits on selected facilities and sector associations (random or risk-based) • Desk-based or full-site

Source Authors 'summary based on Abeelen et al. (2016), EC (2017), Gynther and Suomi (2017), Li et al. (2018), Thollander et al. (2015), Veum (2018), Wakabayashi and Arimura (2016), Zhao et al. (2016)

information among the member companies but also made the industry's action plans and progress publicly available through their websites to improve the transparency of evaluation.

3.4.3 *Lessons for ASEAN Countries*

Table 3.8 summarizes the critical success factors and challenges of voluntary agreements of these five countries. It is found that target setting, incentives and penalties, and monitoring are the most important success factors. There is a consensus in the existing literature that the following three conditions are necessary for successful implementation of various voluntary agreements: (i) ambitious but realistic targets, (ii) enforceable incentives and penalties, and (iii) strong monitoring and evaluation (Cornelis 2019, OECD/IPEEC 2016, Rezessy and Bertoldi 2011).

Ambitious but Realistic Targets

Setting energy-saving targets is one of the most critical steps in designing an effective voluntary agreement scheme. The targets in terms of energy savings or CO_2 emissions reduction should be sufficiently ambitious to guarantee the effectiveness and integrity of the scheme (Cornelis 2019). At the same time, they should be realistic so that companies and industries can achieve the target with a range of economically and technically feasible measures.

Table 3.8 Success factors and challenges of selected voluntary agreements

Country	Success factors	Challenges/limitations
People's Republic of China	• Mandatory target setting • Clear penalties for failing to achieve the targets	• Small coverage during phase 1 (Top-1,000 Energy-Consuming Enterprises program)
Finland	• Proper monitoring and evaluation, strong results and communication of results → increasing motivation and further improving results	• Ensuring timely submission of good-quality data requires a lot of administrative work
Japan	• A robust target which is consistent with the government's long-term projections • The quality of the plan is secured based on plan-do-check-act (PDCA). → Reliable transparency and credibility compared to other measures that have no review process	• Narrow sector coverage: It includes only large-scale enterprises that are members of the Keidanren • Enforcement: No public administrative organization is explicitly engaged in compelling compliance
Netherlands	• Incentives: tax exemption and automatic compliance with the energy-related provisions under the Environmental Management Act • All data in the monitoring reports are verified their completeness and correctness by external consultants	• Since the LTA and LEE are part of a combination of policy instruments for energy efficiency improvement, measuring and isolating their effect is challenging
United Kingdom	• A stick-and-carrot approach: setting up a monitoring and assessment system to provide a discount on the tax and impose a penalty for non-compliance • Two-tier target setting structure → Instead of direct interactions between the government and the companies, the subsector associations are responsible for the operations and communication, which enhances administrative efficiency and facilitates effective sharing of sector-specific expertise	• A combination of collective and individual liability decreases fairness and accountability. → An incentive for individual companies to free ride

LTA long-term agreement, *LEE* long-term agreement on energy efficiency. *Source* Authors' own elaboration

To set realistic but ambitious targets satisfying both the government and the participating enterprise or industries, a consensus-seeking approach through multiple stakeholder engagement plans will be fundamental in the process of target setting and rule definition for the voluntary agreement (ATEE 2017). In the UK, the government often tended to require industry associations to adjust the targets to a more challenging level during the negotiation of the CCA (Abdelaziz et al. 2011).

If the ASEAN countries introduce or expand voluntary agreements in the future, the energy-saving targets should be ambitious enough to achieve national energy efficiency targets. Collective regional targets of ASEAN should be reflected and adjusted as well. Also, the negotiations to determine the energy-saving targets are likely to be strengthened. Talks between the government and partner companies will enable the government to seek more ambitious targets. However, it should be noted that the targets have to be commensurate with the technical and financing capabilities of the companies and government. Therefore, it is essential for the government to have a better understanding of the technical and economic potential of energy efficiency in specific industries (Fawkes et al. 2016).

Effective and Enforceable Mechanism

While it is acknowledged that voluntary agreements have been successfully implemented to some extent, lower participation level is still observed in many jurisdictions compared to the coverage of other regulatory or economic instruments. As shown in the voluntary agreements of these five countries, successful voluntary agreements have designed both government support conditional on the participation and penalty associated with non-compliance.

The incentive most frequently used in voluntary agreements is financial assistance, including subsidies and tax rebates. Companies are often reluctant to make additional investments but expect to receive financial support from the government in exchange for their energy efficiency initiatives. Thus, the financial assistance mechanism needs to be carefully investigated to avoid free riders while motivating companies to join the voluntary agreements.

Access to information, including training programs and network meetings, is also an important incentive for companies. In Japan, industry associations have helped participating companies to develop a shared understanding of the targets and feasible measures by providing them with periodic training sessions. According to a survey conducted by Japan's Ministry of Economy, Trade and Industry, 64% of companies recognized the information provided by the industry associations under the Keidanren Voluntary Action Plan as being useful (Wakabayashi and Arimura 2016). In most cases, small and medium-sized enterprises will benefit more from networking as they are often confronted with the constraints of time, budget and capacity in collecting relevant information and best practices in the given industry.

In addition to these incentives, most of the voluntary agreements combine penalty mechanisms, including repayment of subsidies and discontinuation of tax rebates, to discourage noncompliance with pre-agreed commitments. The penalties may make the voluntary agreement scheme function as a mandatory measure to associate pressing threats with non-achievement of the targets. Although mandatory targets may induce a high compliance rate and program effectiveness, setting a binding target can spark strong opposition within the industry sector. Also, the voluntary nature of voluntary agreements makes it challenging to incorporate any legal penalties in the sanction schemes. The cases of Finland and the UK may provide good examples. With the same approach, the other countries can also make companies choose to either achieve the target and enjoy financial benefits or not achieve the target and give up the benefits. Thus, this may lower the resistance of companies compared to regulatory measures by relieving their legal burden for compliance.

Therefore, voluntary agreements of the ASEAN countries need to improve their effectiveness with the introduction of a well-designed enforcement system to provide participating companies with negative incentives as well as positive incentives. Also, it is worthwhile considering nonfinancial incentives together with financial incentives. For example, a regular network meeting where the network members exchange information and their experiences should be promoted. Furthermore, the threat of disclosing noncompliance results can also work as a negative incentive as in the Japanese case.

Strong Monitoring and Evaluation Mechanism

Reporting, monitoring, and evaluating are considered the weakest points of voluntary agreements because the evaluation has relied on self-reporting from the industry in many cases. Thus, employing transparent and confirmable procedures for monitoring and evaluation is critical for the successful operation of voluntary agreements (Rezessy and Bertoldi 2011; Tanaka 2011). Indeed, all five cases show that successful voluntary agreements have ensured reliable monitoring and evaluation mechanisms including robust indicators, third-party verification. and information disclosure to the public.

The voluntary agreements of the five countries may provide lessons for designing monitoring and evaluation mechanisms for future voluntary agreements. First, the results reported by each company need to be verified by a specialized group comprised of external consultants and experts. Over-dependence on self-reporting by industry may exacerbate the existing information asymmetry between the government and the industry. To address this issue and improve the accuracy of self-reported data, an independent third-party verifier, responsible for checking baseline and monitored data, needs to be hired before the agreement is enforced (Rezessy and Bertoldi 2011). Japan's approach offers an alternative if hiring external consultants is likely to cause a significant burden on the companies and the government. Under the Keidanren Voluntary Action Plan, an evaluation committee was set up in 2012 to verify data and assess the progress of the program. The committee was composed of seven to ten members from academia, media, nongovernment organizations, and labor unions.

An online reporting system should also be considered to simplify the reporting process and ease the administrative burden of the participants (Rezessy and Bertoldi 2011). Finally, better incentives are required to ensure that companies provide reliable data (Veum 2018). The Finnish government has stated that one of the challenges faced by the Finnish Energy Efficiency Agreements for the Industrial Sector was related to the quantity and quality of data. The program observed a lack of data and difficulty in producing good-quality data within the due date of submission due to the intensive administrative work (Gynther and Suomi 2017). Thus, it is important to put in place appropriate logistics to enable participating companies to provide timely and accurate data during the reporting process. In addition, once the voluntary agreements are implemented, thorough cost–benefit analysis to evaluate their impact and outcomes should be conducted to provide feedback for the continuous improvement of the program (Tractbel ENGIE 2018).

3.5 Conclusion and Policy Implications

The ASEAN countries are set to make major strides toward improved energy efficiency, given the growing energy demand. The current regional and national energy efficiency improvement targets are not ambitious yet. It is thus necessary to strengthen the efforts of energy efficiency with a more bottom-up approach. Moreover, the ASEAN countries are facing challenges that hamper the expansion of energy efficiency financing, including a lack of awareness of the importance of energy efficiency and limited technical capacity of companies. Voluntary agreements to improve industrial energy efficiency can be an effective policy option for the ASEAN countries to solve these challenges, given the engagement of multiple stakeholders on a voluntary basis. They can contribute to alleviating information asymmetry by enabling the government to estimate technically and economically feasible energy-saving potential through a dialogue with industries.

Voluntary agreements are flexible enough to be integrated into the existing policy mix, and their effectiveness tends to increase when they are combined with other policy instruments, such as energy audits, educational programs, and subsidies (Lindén and Carlsson-Kanyama 2002; Zhang et al. 2018b). It suggests that voluntary agreements are able to not only promote energy efficiency financing by strengthening the capacity of energy efficiency market actors, but also improve the effectiveness of energy efficiency financing schemes and unwanted negative side-effects by combining with the financing schemes. For example, if achieving the targets set through voluntary agreements is a precondition for being a beneficiary of the financing schemes, it can ease the screening process of financial institutions and avoid moral hazard. Furthermore, the flexibility of voluntary agreements means that the ASEAN countries may easily initiate voluntary agreements without significant institutional change compared to other traditional regulatory and fiscal instruments.

Based on the five countries' experience, this chapter suggests three major design elements as essential factors for well-functioning voluntary agreements: ambitious and realistic target setting, effectively enforceable incentives and penalties, and a strong monitoring and evaluation mechanism. Besides, tailoring the design of the program to the unique conditions of each country is necessary to maximize the effectiveness of voluntary agreements. Lastly, transparency must be ensured because voluntary agreements can only be the most effective when trust and cooperation exist between the government and target companies.

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Chapter 4
R&D Investments in Energy Efficiency, Economic Impact, and Emissions Abatement

Di Yin and Youngho Chang

Abstract Despite the small share in total energy investments, energy investments in research and development (R&D) incubate early-stage energy technology, improve energy efficiency in the manufacturing processes, and facilitate the expansion of green energy systems. This chapter distinguishes R&D investments in energy efficiency from other energy R&D investments. Our research formulates the way in which R&D investments in energy efficiency enhance energy production through efficiency knowledge accumulation. Our research explores how R&D investments in energy efficiency affect the other types of energy R&D investments, total energy R&D investments, and the share of energy R&D investments in the capital goods sector. Also, the study examines the impact of R&D investments in energy efficiency on economic welfare, economic structure, carbon taxes, energy transition, carbon emissions, and climate change. The study simulates three emissions abatement scenarios: an optimal abatement scenario, a 2 °C policy scenario, and a 1.5 °C policy scenario. Our study provides a reference level for the amount of R&D investment in energy efficiency. Policy makers may overinvest in other energy R&D investments under all abatement scenarios if they overlook R&D investments in energy efficiency. R&D investments in energy efficiency also bring considerable economic gains, however, its climate impact is not significant.

Keywords R&D investments · Energy efficiency · Carbon tax · Energy substitution · Backstop technology · Benefit-cost analysis

JEL Classification Q52 · Q55 · Q58

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4.1 Introduction

Financing energy-related projects receives considerable attention due to its significant impact on energy production, energy value-chain enhancement, energy security, and global-warming mitigation. The public sector and private sector fund energy projects in various sectors ranging from the oil and gas supply sector, the coal supply sector, the power sector to energy efficiency, and renewable technology for transport and heat. Among total energy investments, energy research and development (R&D) investments amounted to $122.7 billion in 2018, accounting for 6.66% of the overall energy investment (IEA 2019). Despite the small share, R&D investment incubates early-stage energy innovation, enhances energy efficiency in manufacturing processes, and encourages the development of emissions reduction technology (e.g., renewable technologies and carbon capture and storage).

According to the report on world energy investments (IEA 2019), energy R&D investments in low-carbon technology dominates the total energy R&D investments, accounting for four-fifths of the total energy R&D investments. The rest of the R&D investments focus mainly on energy-saving technology. This chapter explicitly distinguishes the two types of R&D investments: R&D investment in energy efficiency and R&D investment in backstop technology. The former enhances the energy supply chain (e.g., the energy production process and energy transmission process), providing more energy services with the same raw energy. The latter lowers the cost per unit of backstop technology (e.g., solar photovoltaic technology and wind power technology), which improves the comparative advantage of backstop technology and induces the energy transition from fossil fuels to backstop technology.

To align with the book's theme, this chapter focuses on the discussion of R&D investments in energy efficiency. Our study provides several examples of R&D investments in energy-saving technology supported by the United States (US) Department of Energy. The R&D spending is from the energy supply side including a project for combined heat and power (CHP), a project for the next-generation manufacturing processes, a project for the smart grid, and a project for emerging research exploration. The R&D project for CHP develops new technologies (e.g., advanced electricity generation components) and enables the system flexibility to enhance the efficiency of the turbine. The R&D project for the next generation manufacturing processes innovate new materials (e.g., advanced membrane and new catalyst) and new technologies (e.g., waste-heat recovery) to double energy productivity and save energy costs. The R&D project for the smart grid aims to modernize methods to monitor and upgrade electricity distribution and transmission. It enhances the energy system to improve energy efficiency. The R&D project for emerging research exploration focuses on potential breakthroughs in energy efficiency.

Our study formulates R&D investments in energy efficiency to enhance energy production through the knowledge accumulation process. The knowledge of energy efficiency is a stock like physical stock, which is the sum of old knowledge and new knowledge. Old knowledge can be carried from one period to the next period with a knowledge discount rate. New knowledge can be created by R&D investments in energy efficiency and the existing knowledge of energy efficiency. End-use energy services are a combination of raw energy and knowledge of energy efficiency. The knowledge of energy efficiency and raw energy substitutes in the form of constant elasticity of substitution. The knowledge creation processes reflect how R&D investments in energy efficiency enhance energy production from the supply side. It is consistent with the above R&D practices.

Our study develops a two-R&D and two-sector climate–economy model. The model contains two sectors: the capital goods sector and the consumption goods sector. It enables the separation of investment from consumption and facilitates the investigation of R&D allocation. Our study simulates two scenarios for R&D investments. The base scenario only considers R&D investments in low-carbon technology, which is the mainstream of energy R&D investments. The other scenario is with R&D investments in energy efficiency, where the model considers both types of energy R&D investments. Our study considers the above two R&D scenarios under various emissions abatement policies: an optimal abatement policy, a 2 °C policy scenario, and a 1.5 °C policy scenario.

The model considers a long-term policy decision as CO_2, once emitted, stays in the atmosphere for more than 50 years. The long-term abatement policy induces a technological change in energy use through the channel of R&D investments. Our study explores the amount of R&D investments in energy efficiency with various abatement policies. Also, it examines the effect of R&D investments in energy efficiency to R&D investments in low carbon technology and total R&D investments. The chapter provides policy insights for the impact of R&D investments in energy efficiency on economic welfare, economic structure, and carbon taxes. It also investigates how much R&D investments in energy efficiency affects energy substitution, emissions abatement, and climate change.

The organization of this report is as follows. Section 4.2.1 describes the trends of the energy R&D investment amount. Section 4.2.2 presents cutting-edge R&D projects funded by the US Department of Energy to illustrate the R&D investments in energy efficiency from the supply side. Section 4.3 reviews the literature related to energy efficiency financing and the induced technological change in the climate economy field. Section 4.4 develops the modified top-down model. Section 4.5 presents the policy regimes of energy taxes and various emissions abatement policies. Section 4.6 summarizes the results of R&D investments, economic welfare, and climate change. Section 4.7 provides some policy insights on evaluating the R&D investments in energy efficiency from the economic perspective and the climate perspective.

4.2 R&D Investments in Energy Efficiency

4.2.1 Description of Energy R&D Investments

Energy R&D investment reaches $122.7 billion (current currency) in 2018, accounting for 6.66% of the total energy investment. Figure 4.1 presents the energy R&D spending in the public sector and the private sector in 2016, 2017, and 2018. The public spending on energy R&D reaches $28.7 billion (current currency) in 2018, accounting for one-fifth of the total energy R&D investment. In contrast, the corporate spending on energy R&D is $94 billion (current currency), which is four times the public spending. The total energy R&D investment keeps increasing from 2016 to 2018. The public spending on energy R&D climbs by 8.0% from 2016 to 2017, while the rate of increase slows down to 2.8% from 2017 to 2018. The corporate spending on energy R&D remains stable from 2016 to 2017 while it increases by 4.3% from 2017 to 2018.

Energy investment in research and development plays an important role in energy innovation. It enables energy systems to adopt new and affordable technologies. Energy R&D reshapes the energy system by improving the energy efficiency of the existing energy technology as well as by lowering the cost of advanced energy technology. For example, R&D investments in heating and cooling systems enable a building to be more energy efficient by improving the mechanical insulation, the air-sealed quality, and the performance of the glazing. Other energy R&D investment includes spending in the electricity sector, such as electricity storage and smart electricity systems, and spending on better fuel combustion technologies.

Energy R&D also facilitates the slowing down of global warming and the meeting of environmental goals (e.g., the Paris Agreement). Figure 4.2 presents

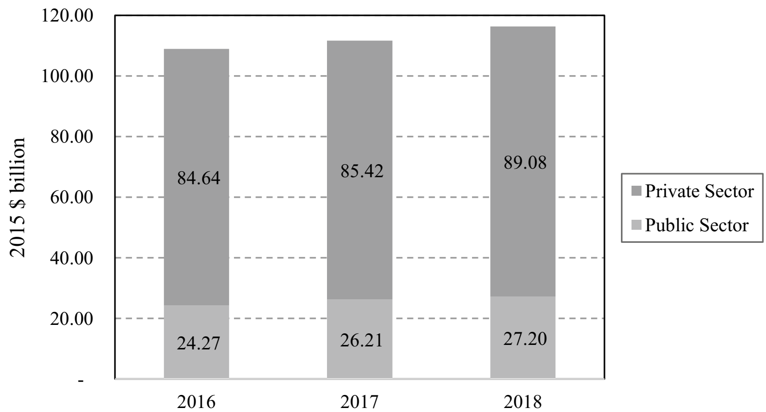


Fig. 4.1 Energy R&D investment in the public sector and the private sector (2015 $ billion). *R&D* research and development. *Sources* IEA (2017, 2018, 2019)

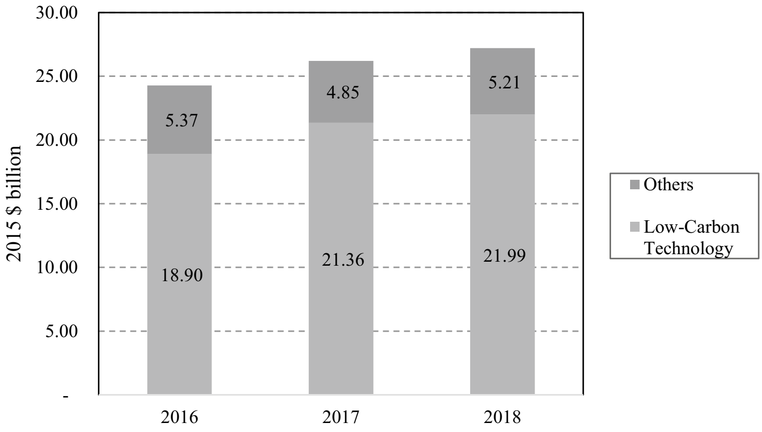


Fig. 4.2 Government spending on energy R&D investment (2015 $ billion). *R&D* research and development. *Sources* IEA (2017, 2018, 2019)

public spending on energy R&D in 2016, 2017, and 2018. In 2018, of the total public spending on energy R&D investment, more than four-fifths of spending was on low-carbon technology, amounting to $21.99 billion (constant 2005). It jumped by 13.5% from 2016 to 2017 and slightly increased by 2.9% from 2017 to 2018. Low-carbon R&D investment enhances the existing low-carbon equipment (e.g., wind turbines) as well as providing funding for cutting-edge innovations, which are expensive at the early stage and have an uncertain market value. Low-carbon R&D investment improves the competitive advantage of low-carbon technology and facilitates the energy transition from fossil fuels to clean energy, which has a significant impact on emissions abatement.

Despite the increasing trend of energy R&D investment, scholars are still concerned that the investment in energy R&D is insufficient to meet the long-term goal of the Paris Agreement, which restricts the atmospheric temperature rise to under 2 °C by 2100. Given the current energy R&D investment, new low-carbon technologies, such as carbon capture and storage, low-carbon freight transport, and energy efficiency, are not showing significant signs of being developed rapidly enough (IEA 2016). Less speedy adoption slows down the energy transition from traditional fossil fuels to clean energy. In 2015, 24 countries participated in a global initiative to accelerate public and private clean energy innovation to mitigate climate change (Mission Innovation 2020). The member countries committed to doubling R&D funding over 5 years and inducing an increase in private spending on low-carbon technologies.

4.2.2 *Energy Efficiency R&D Projects from the Supply Side*

This subsection selects some projects of R&D investments in energy efficiency from the supply-side to illustrate the way R&D investments in energy efficiency improve the energy services in the production process.

R&D for Smart Grid

The US Department of Energy financed a multiyear program from 2010 to 2014 for smart grid R&D. According to the multiyear program plan (US DOE 2012), this program aims to modernize the nation's electricity transmission and distribution system and implement smart grid technologies, tools, and techniques. The tasks include accelerating the deployment and integration of advanced communication, control, and information technologies. The integrated advancement in electricity operations helps sense, collect, and report performance information. The smart grid system can monitor and diagnose energy efficiency problems. The energy efficiency problems can be solved from the end-user perspective. For example, demand response provides feedback to the end user to improve energy efficiency. It is subtle to use smart grid capabilities to encourage and support energy efficiency goals.

R&D for Combined Heat and Power

The US Department of Energy has funded various combined heat and power (CHP) R&D projects with a budget up to $10 million since 2018. CHP is an integrated set of technologies for the simultaneous, on-site production of electricity and heat. The projects aim to enable small-to-medium-sized manufacturers to use CHP systems to provide services to the electricity grid. The R&D breakthroughs are mainly from three perspectives: (i) developing power electronics and control systems that help link flexible CHP systems to the grid, (ii) upgrading electricity generation components that enable CHP systems to be more responsive to the demands of the modern electricity grid, (iii) improving the efficiency of turbines used in flexible CHP systems (US DOE 2020a). The CHP R&D projects examine how the new materials and advanced manufacturing technology can increase the efficiency of turbines used in CHP systems. Also, they test how high-temperature materials can enable high-efficiency power generation.

R&D for Next Generation Manufacturing Processes

The US Department of Energy funded various R&D projects for next-generation manufacturing processes (US DOE 2020c). It intends to upgrade the manufacturing processes and further double net energy productivity, facilitates the improvement in energy efficiency in the manufacturing processes and the high-quality products with low-energy costs. The R&D area focuses mainly on (i) reactions and separations, (ii) high-temperature processing, (iii) waste heat minimization and recovery, and (iv) sustainable manufacturing.

The first R&D area (reactions and separations) develops new technologies and new materials for energy-efficient industrial separations, distributive distillation processes, advanced water removal processes, and ultra-high-efficiency aluminum production. The advanced materials and methods provide high energy efficiency and process intensification that improve energy efficiency and cut energy costs. It can be applied to various manufacturing industries, including oil refining, food processing, and chemical production. The second R&D area (high-temperature processing) enables or enhances water-based, the selective extraction of critical materials from low-grade ores; the recovery of high-value materials in obsolete electronic equipment and waste; and low-temperature, high-efficiency chemical or electrochemical processes. It enables flexible fuel-combination in production processes, induces energy-efficient production, and minimizes the carbon emissions in the manufacturing processes. The third R&D area (waste heat minimization and recovery) facilitates technological advances in ultra-efficient steam production, high-performance furnaces, and innovative waste heat recovery. It improves sustainability, reduces water use, and lowers the energy footprint of the manufacturing industry. The fourth R&D field (sustainable manufacturing) reduces process steps and materials use, and enhances the manufacturing value chain. A featured program for energy efficiency is in energy-saving melting and revert reduction technology (E-SMARRT).

Emerging Research Exploration

The US Department of Energy supports the emerging research exploration program (US DOE 2020b). The program provides opportunities to perform early-stage R&D of new technologies. It encourages new partners to contribute to the research exploration and reduce the technical risk borne by the new entries. The funding aims to develop new technologies and potential breakthrough materials for industrial manufacturing. It covers three main areas: (i) advanced materials, (ii) advanced processes, (iii) modeling and analysis tools for materials and manufacturing.

The first area (advanced materials) develops new materials in harsh service conditions, for direct thermal energy conversion and new highly-effective chemical catalysts. The second area (advanced processes), aims to enhance intensified manufacturing processes, lower cost waste heat recovery, and minimize the carbon emissions in the manufacturing processes. The third area develops the optimization method to shed light on how manufacturers use energy and materials across the lifecycle of their products through information technology and knowledge systems.

4.3 Literature Review

This chapter is mainly relevant to two streams of existing studies. Section 4.3.1 documents the literature related to energy finance. Section 4.3.2 summarizes the key studies related to induced technological change and energy R&D investment.

4.3.1 Financing Energy Projects

Retallack et al. (2018) conducted case studies for energy efficiency finance programs. Their paper examines the best practices to leverage private green finance. They investigate the energy efficiency projects in various countries including the property assessed clean energy program in the US, the green deal in the United Kingdom (UK), the carbon trust energy efficiency program for small-and-medium-sized enterprises in the UK, commercialization of the sustainable energy finance program in Turkey, the utility-based energy efficiency finance program in the People's Republic of China, the energy efficiency services limited program in India, and the energy efficiency revolving fund in Thailand. The paper emphasizes the importance of policy implementation from the energy supply side and awareness from the energy demand side. To link the supply and demand, projects need to be prepared in a commercially viable way and guarantees the sustainability in the long term. It is also important to train local suppliers of goods and services to understand different technologies and to build the capacity to conduct the basic monitoring processes.

Gouldson et al. (2015) explore innovative financing mechanisms such as revolving funds. The revolving funds collected from the savings of the existing investments in energy efficiency and low-carbon development can be recovered and reinvested in some of the savings generated by early investments. The study develops a generic revolving fund model and conducts a benefit-cost analysis in the context of the UK. The paper concludes that revolving funds could cut down the cost of UK retrofits by 26%. The funds could achieve cost-neutral retrofits in the long term and dramatically increase low-carbon investments.

Yoshino et al. (2019) demonstrate the investment gap between fossil fuel projects and green energy projects. The relatively insufficient investments in green energy are due to the lower return rate compared to fossil fuel projects. This paper proposes a model to use the tax revenue spillover of green energy supply by returning the portion of tax revenue to green energy projects. This effectively enhances the return rate of green projects. They provided a social community-based funding scheme for smaller green projects.

Similar to Yoshino et al. (2019), Taghizadeh-Hesary and Yoshino (2019) propose two applied theoretical frameworks to illustrate the tax return generated from the spillover effect of green energy supply to investors. It can lower the risk of financing green energy and increase the return rate of green energy projects. Technical developments in the sphere of distributed ledger technologies increase the transparency in green finance and investments. The tax return scheme might be an effective method to induce private investment in green energy.

Differentiating from Gouldson et al. (2015); Yoshino et al. (2019), and Taghizadeh-Hesary and Yoshino (2019), our study aims to explore energy finance in energy efficiency. The first paper in our review (Retallack et al. 2018) provides case studies focusing on energy efficiency finance from both the supply side to the demand side. Our study mainly limits our scope from energy investments from the supply side. Also, our study measures the economic impact and climate impact induced by R&D investments in energy efficiency from the knowledge accumulation approach.

4.3.2 Induced Technological Change and Energy R&D Investment

One stream of literature relates to the role of energy R&D investment in economic growth. Popp (2004) considered endogenous technological change with R&D investment in energy efficiency in a climate–economy framework with environmental externalities. Like a physical investment, R&D investment facilitates the accumulation of knowledge in energy services. This study adopts a learning-by-researching function to model the evolution of energy knowledge. Energy R&D investment combines with the existing energy knowledge to boost energy technological change. Popp (2004) concludes that ignoring R&D in energy saving leads to an underestimation of economic welfare. Besides, R&D in energy-saving reduces the emissions abatement cost.

Popp (2006) extended his 2004 research by endogenizing the technological change in backstop technology. He considered both R&D investment in energy efficiency and R&D investment in backstop technology. R&D investment in backstop technology boosts the energy knowledge and lowers the cost of backstop technology per unit of energy services. He concluded that there are larger welfare gains from R&D investment in backstop technology.

Sue Wing (2003) investigated the potential of the carbon tax to induce technological change through induced R&D using a computable general equilibrium model. He examined the resource relocation and the accumulation of energy knowledge at the industry level and found that the impact of induced technological change is large and positive and that the input substitution effect, which mitigates most of the deadweight loss of the tax, dominates it.

Yin and Chang (2020) identified two types of R&D investment in energy-saving technology and backstop technology. They modeled the way R&D investment in backstop technology alters the energy transition from conventional energy to clean energy. The study added energy micro-foundations to the traditional climate–economy framework. It concluded that R&D investment enhances economic welfare and boosts the energy transition from fossil fuels to backstop technology. A more restrictive abatement policy hurts the welfare in the short term while improving it in the long term.

4.4 Model

4.4.1 Utility

Consider an infinite-horizon economy in a discrete-time model, in which a social planner makes consumption, physical investment, and energy R&D investment decisions to maximize the expected utility:

$$\max V = \sum_{t=0}^{\infty} L_t \cdot \frac{c_t^{1-\alpha}}{1-\alpha} \cdot (1+r)^{-t} \tag{4.1}$$

where r is the pure rate of the social time preference, $\alpha \in (0,1)$ is the coefficient measuring inequality aversion, L_t is the aggregate labor supply, and c_t is the consumption per capita. Consumption in this study is a broad concept that includes not only traditional market purchases of goods and services, like food and shelter, but also nonmarket items, such as leisure, cultural amenities, and enjoyment of the environment. This conventional feature is in line with most environmental economics research, such as Nordhaus (1994), Nordhaus (2014), Nordhaus and Boyer (2003), and Popp (2004). The social planner aims to maximize a social welfare function that is the discounted sum of the utility of the per capita consumption.

4.4.2 Production Sector

This study considers $N = 2$ sectors, using the index i, named the capital goods sector and the consumption goods sector. Each sector produces a good that can be used for investment or consumption. This disaggregation of production enables us to capture a meaningful energy transition pattern in different sectors and to build our results on realistic micro-foundations for energy use. Each sector produces goods i in period t using capital K_{it}, labor L_{it}, and energy service ES_{it} following a Cobb–Douglas form of the production function with capital and energy service shares $\beta_i, \gamma_i \in (0,1)$. A_{it} represents the total factor productivity in sector i. Our model considers the negative impact of the increase in the atmospheric temperature on the gross output. Specifically, a higher atmospheric temperature induces a smaller damage factor (Ω_t) and thus a smaller net output. The net output Y_{it} in sector i in period t is the gross output ($A_{it}K_{it}^{\beta_i}ES_{it}^{\gamma_i}L_{it}^{1-\beta_i-\gamma_i}$) times the damage factor Ω_t, deducting the energy cost EC_{it}, which Eq. (4.2) below shows:

$$Y_{it} = \Omega_t A_{it} K_{it}^{\beta_i} ES_{it}^{\gamma_i} L_{it}^{1-\beta_i-\gamma_i} - EC_{it} \tag{4.2}$$

This study allocates the production in the capital goods sector Y_{1t} to various investments, including physical investment I_t, the R&D investment in energy-saving RE_t, and the R&D investment in low-carbon technology RB_t.

Equation (4.3-1) presents investment allocation in the capital goods sector. This study explicitly identifies R&D investments in energy efficiency and low-carbon technology. Separating the two types of R&D investments helps to model the unique characters of R&D investments in energy efficiency. Section 4.4.3 will present the way in which R&D investments in energy efficiency improves the energy services from the supply side through the knowledge transformation.

As shown in Eq. (4.3-2), consumption goods Y_{2t} go to consumption C_t, which this study uses as a numeraire.

$$Y_{1t} = I_t + RE_t + RB_t \tag{4.3 − 1}$$

$$Y_{1t} = C_t \tag{4.3 − 2}$$

Capital stock accumulates over time through physical investment I_t produced in the capital goods sector.

$$\sum_i K_{it+1} = (1 - \delta_K) \sum_i K_{it} + I_t \tag{4.4}$$

where $\delta_K \in (0, 1)$ is the rate of capital depreciation and $K_{i0} > 0$ is given.

4.4.3 Modeling Energy Services and R&D Investments in Energy Efficiency

This study models R&D investments in energy efficiency to enhance energy services through the knowledge accumulation of energy-saving technology. It assumes that the knowledge stock of energy-saving technology and the raw energy are substitutes. Either the use of raw energy or the advances of the knowledge stock regarding energy-saving technology can meet the energy needs. This assumption is in line with Popp (2004), Popp (2006), and Yin and Chang (2020).

Energy service ES_{it} is the combination of raw energy input ER_{it} and the knowledge stock of energy-saving technology H_{Et} with constant elasticity of substitution, which is shown in Eq. (4.5).

$$ES_{it} = A_E \left(a_E H_{Et}^{\sigma} + (1 - a_E) ER_{it}^{\sigma} \right)^{1/\sigma} \tag{4.5}$$

where the scale parameter $A_E > 0$, the weight parameter $a_E \in (0, 1)$, and the substitution parameter $\sigma \in (0, 1]$.

The knowledge stock of the energy-saving technology evolves similarly to the capital stock. The knowledge of energy efficiency can be carried over from period t to period $t + 1$ with a depreciation rate δ_H. Knowledge creation depends on the existing energy knowledge and R&D investments in energy efficiency. We model the process of knowledge creation following the “learning-by-researching” approach, which Barreto and Kypreos (2004), Miketa and Schrattenholzer (2004), Popp (2004), and Popp (2006) adopted.

$$H_{Et} = (1 - \delta_H)H_{Et} + \varphi_{m1} R_{Et}^{\varphi_{m2}} H_{Et}^{\varphi_{m3}} \tag{4.6}$$

Raw energy combines carbon-based fossil fuels and low-carbon technology B_{it} (such as wind energy and solar energy), which is called backstop technology in most economic literature. This model considers $M = 3$ representative carbon-based fossil fuels in each sector, which it indexes with $J = P, W, G$, namely oil products P_{it}, coal products W_{it}, and natural gas G_{it}. The disaggregation of energy types enables us to investigate the pattern of the energy transition.

$$ER_{it} = \sum_J J_{it} + B_{it}, J = P, W, G \tag{4.7}$$

This study assumes a linear combination of different energy products as we can measure each energy production in the same unit, such as a barrel of oil equivalent (boe) or a ton of oil equivalent (toe). The assumption is in line with the literature related to the energy transition, such as Chakravorty et al. (1997), Chang (1999), and Yin and Chang (2020).

The initial resource stock $S_{J0} > 0$ restricts the depletion of carbon-based fossil fuels over time. This study assumes that the resource stock remains constant over the years. A limited resource stock induces a scarcity rent upon resource extraction. However, the available resources may change in the long run as the extraction technology improves or as new resource stock is discovered. This discussion is beyond our scope.

$$\sum_i J_{it} \leq S_{Jt} - S_{Jt+1} \tag{4.8}$$

The energy cost EC_{it} appearing in Eq. (4.2) is the sum of the cost per unit of each fossil fuel $p_{iJt} > 0$ and the cost per unit of backstop technology p_{iBt} with $p_{iB0} > 0$.

$$EC_{it} = \sum_J p_{iJt} J_{it} + p_{iBt} B_{it} \tag{4.9}$$

The cost of backstop technology p_{iBt} declines over time as the knowledge stock of backstop technology H_{Bt} accumulates. Backstop energy, such as wind power and solar power, achieves higher efficiency levels and lower costs by increasing the installation capacity due to economies of scale.

$$p_{iBt} = \frac{p_{iB0}}{(H_{Bt})^b} \tag{4.10}$$

where $0 < b < 1$ is a scale parameter. Thus, the increases in the knowledge stock of backstop technology lead to decreases in the cost of backstop technology, but they are less than proportional. This assumption is consistent with Popp (2006), Hart (2008), and Yin and Chang (2020).

The knowledge stock of the backstop technology evolves similarly to the knowledge stock of energy efficiency as shown in Eq. (4.11).

$$H_{mt} = (1 - \delta_H)H_{mt} + \varphi_{m1} R_{mt}^{\varphi_{m2}} H_{mt}^{\varphi_{m3}}, m = E, B \tag{4.11}$$

where $\delta_H \in (0, 1)$, $\varphi_{m1} > 0$ is a scale parameter, and $\varphi_{m2}, \varphi_{m3} \in (0, 1)$ are exponential parameters meaning that knowledge creation has diminishing returns on R_{mt}, H_{mt}.

4.4.4 Emissions and Regulation

Our study treats carbon emissions as byproducts of fossil fuel combustion. Each unit of specific fossil fuels emits an amount $\in_J, J = P, W, G$ tons of carbon independent of the processing method. We assume that different uses or processing methods do not affect the carbon emissions while burning each unit of a specific fossil fuel, which is in line with Metcalf (2009). We present the total carbon emissions below.

$$EM_t = \sum_i \sum_J \in_J J_{it}, J = P, W, G \tag{4.12}$$

Carbon emissions enter the atmosphere and are involved in carbon circulation among the atmosphere, the upper ocean, which serves as a quickly mixing reservoir, and the deep ocean, which we assume to be "an infinite sink for carbon" (Nordhaus 1994). The accumulation of greenhouse gases (GHGs) forms a radiative force that drives up the atmospheric temperature. The increase in the atmospheric temperature harms the gross production through the damage factor Ω_t. We formulate the carbon exchange and the radiation process following Nordhaus (2014). Readers who are interested in carbon circulation may refer to Nordhaus (2014).

4.5 Policy Regimes

This study examines two R&D investment scenarios:

(a) Base scenario, in which policy makers only invest in the R&D of backstop technology.

(b) R&D in energy efficiency scenario (denoted as R&D in efficiency [RE] scenario), in which policy makers invest in both R&D of energy efficiency and R&D of backstop technology.

This study investigates three emissions abatement policies:

(a) An optimal policy scenario in which the marginal cost of CO_2 reduction equals the marginal benefit from the emissions abatement.
(b) A 2 °C policy scenario in which the atmospheric temperature change is below or up to 2 °C above the pre-industrial levels, which is the goal of the Paris Agreement; we determine the emissions control rate optimally to maximize the objective function subject to the temperature target.
(c) A 1.5 °C policy scenario in which the atmospheric temperature change is below or up to 1.5 °C above the pre-industrial levels, which the Intergovernmental Panel on Climate Change proposed in its special report in 2018 (IPCC 2018); we determine the emissions control rate optimally to maximize the objective function subject to the temperature target.

4.6 Results

4.6.1 R&D Investments

This subsection first presents the amount of R&D investment in energy efficiency. Second, the results indicate R&D investments in energy efficiency slightly crowd out R&D investments in backstop technology. Third, the results show policy makers tend to invest in energy R&D insufficiently when overlooking the R&D investments in energy efficiency. Fourth, the share of energy R&D investments in total investments slightly increases when the model considers R&D investments in energy efficiency.

Figure 4.3 shows the amount of R&D investment in energy efficiency by 2100 with various abatement policies. R&D investment in energy efficiency increases from 2015 to 2070, reaches its highest point ($20.06 billion) in 2070 and then declines after 2070 under the optimal abatement policy. It also has a reverse U-shape curve under the 2 °C policy and the 1.5 °C policy. However, it achieves the highest amount ($20.30 billion) in 2055 with the 2 °C policy and the highest amount ($19.10 billion) in 2045 with the 1.5 °C policy. A more stringent abatement policy (e.g., the 1.5 °C policy scenario) leads to a higher amount of R&D investment in energy efficiency in the short run and reaches the highest amount earlier than a less restrictive abatement policy (e.g., the optimal abatement scenario). It indicates that policy makers should invest more in R&D investments in energy efficiency if they aim to achieve an ambitious abatement goal.

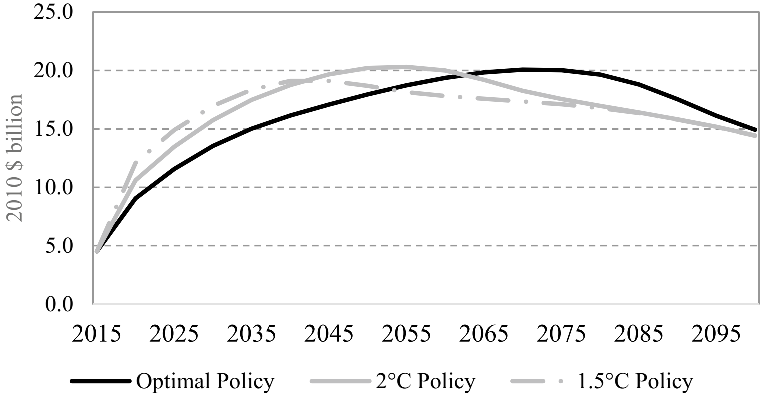


Fig. 4.3 Amount of R&D investment in energy efficiency (2010 $ billion). *R&D* research and development. *Source* Authors' calculations

Figure 4.4 shows the impact of R&D investments in energy-saving technology on R&D investments in backstop technology by 2100. R&D investments in energy efficiency slightly rule out R&D investments in backstop technology. R&D investments in backstop technology shrink by 0.52% in 2020, by 0.46% in 2050, and by 0.35% in 2100 under the optimal abatement policy when the model considers R&D investments in energy efficiency. The crowd-out effect is relatively large in the short run, while it is relatively small in the long run under the optimal abatement case, the 2 °C policy case, and the 1.5 °C policy case. The crowd-out effect keeps decreasing from 2020 to 2100. Among the three abatement scenarios, the crowd-out effect is relatively large in the optimal abatement scenario, followed by the 2 °C policy scenario, and the 1.5 °C policy scenario.

Policy makers appear to invest in energy R&D insufficiently when they do not consider that R&D investments in energy efficiency trigger the increase of final energy services. Figure 4.5 presents the change of energy R&D investment level

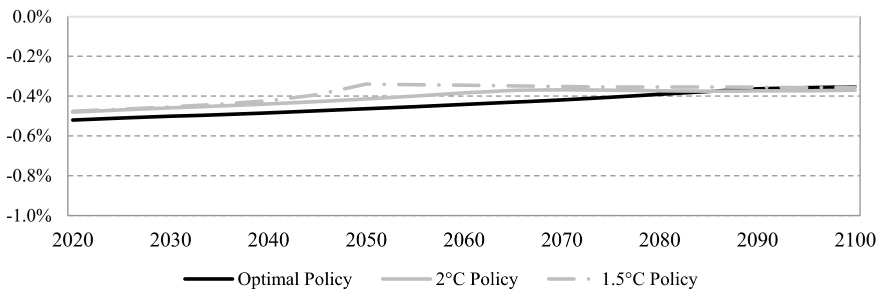
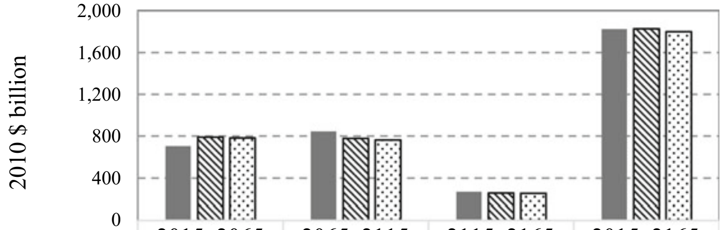


Fig. 4.4 Percentage change of R&D investments in backstop technology (RE scenario vs base scenario). *R&D* research and development, *RE* renewable energy. *Source* Authors' calculations



	2015–2065	2065–2115	2115–2165	2015–2165
■ Optimal Policy	707.5	846.6	270.3	1,824.4
▧ 2°C Policy	791.4	779.0	256.9	1,827.3
⊡ 1.5°C Policy	783.4	762.9	254.2	1,800.6

■ Optimal Policy ▧ 2°C Policy ⊡ 1.5°C Policy

Fig. 4.5 Change in energy R&D investments (RE scenario vs base scenario). *R&D* research and development, *RE* renewable energy. *Source* Authors' calculations

when policy makers consider R&D investments in energy efficiency compared with the base scenario. The entire time horizon is divided into three subperiods: 2015–2065, 2065–2115, and 2115–2165. The underestimation of energy R&D investments is most significant with the 2 °C policy scenario reaching $1,827.3 billion from 2015 to 2165, followed by the optimal abatement scenario ($1,824.4 billion) and the 1.5 °C policy scenario ($1,800.6 billion). The insufficiency of energy R&D investments has a reverse U-shaped curve under various abatement policies. The underestimation effect is more significant in the first two periods from 2015 to 2115 and less significant in the third period from 2115 to 2165.

Policy makers also underrate the share of energy R&D investments in the capital goods sector when they overlook R&D investments in energy efficiency. Figure 4.6 indicates that there is an increase in the share of energy R&D investments in the capital goods sector in the RE scenario compared with the base scenario. The percentage change in the share of energy R&D investments in the capital goods sector also has a reverse U-shaped curve under various abatement policies. The trends are in line with the trends of the underestimation of energy R&D investments. In the short term, the underrated effect is more significant for the share of energy R&D investments in the capital goods sector under a more stringent abatement policy (e.g., the 1.5 °C policy scenario) compared with a less strict abatement policy (e.g., the optimal abatement policy). After 2060, the underrated effect declines and tends to be the same under three abatement policies.

4.6.2 *Economic Impacts*

This subsection discusses the impact of R&D investments in energy efficiency on economic welfare and economic structure. This study uses gross domestic product

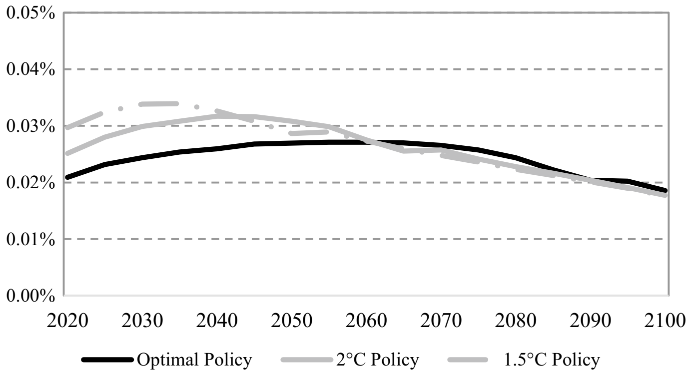
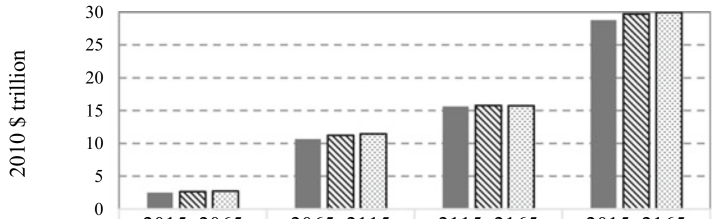


Fig. 4.6 Percentage change in the share of energy R&D investments in the capital goods sector (RE scenario vs base scenario). *R&D* research and development, *RE* renewable energy. *Source* Authors' calculations

(GDP) gains and consumption gains as two economic indicators to reflect how much R&D investments in energy-saving technology can improve economic welfare. This study also analyzes that R&D investments in energy efficiency shape the economic structure of the capital goods sector and the consumption goods sector. This study discusses the impact of R&D investments in energy efficiency on the Pigovian tax. A Pigovian tax is a tax placed on CO_2 that creates negative externalities. The aim of a Pigovian tax is to make the price of CO_2 equal to the social marginal cost.

Figure 4.7 presents GDP gains and consumption gains from 2015 to 2165 when policy makers consider R&D investments in energy efficiency. The accumulated GDP gains from 2015 to 2165 are $28.8 trillion under the optimal abatement policy scenario, $29.7 trillion under the 2 °C policy scenario, and $29.9 trillion under the 1.5 °C policy scenario. The accumulated consumption gains from 2015 to 2165 are $20.7 trillion under the optimal abatement policy scenario, $21.5 trillion under the 2 °C policy scenario, and $21.9 trillion under the 1.5 °C policy scenario. The GDP gains and consumption gains are less significant in the short term and more significant in the long term. It means that R&D investments in energy efficiency have a far-reaching impact on the GDP gains and consumption gains by the knowledge accumulation of energy efficiency. The results also indicate that the R&D investments in energy efficiency induce more GDP gains and consumption gains with a more restrictive abatement policy than with a less stringent abatement policy. R&D investments in energy-saving technology improve the GDP and consumption more effectively under a more stringent abatement policy.

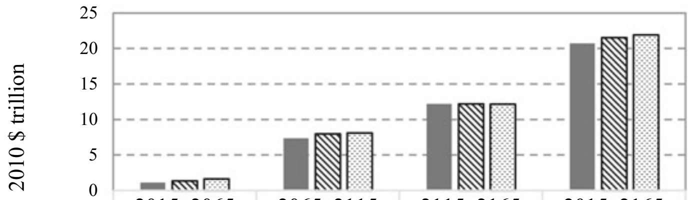
R&D investments in energy efficiency also slightly affect the output allocation between the capital goods sector and the consumption goods sector. This study calculates the share of the capital goods sector in the total production for the base scenario and the RE scenario. Figure 4.8 presents the difference in the share of the capital goods sector in total output between the RE scenario and base scenario. The



	2015–2065	2065–2115	2115–2165	2015–2165
Optimal Policy	2.5	10.6	15.6	28.8
2°C Policy	2.7	11.3	15.8	29.7
1.5°C Policy	2.7	11.5	15.7	29.9

Optimal Policy 2°C Policy 1.5°C Policy

(a) GDP gains (RE scenario vs base scenario)



	2015–2065	2065–2115	2115–2165	2015–2165
Optimal Policy	1.1	7.4	12.2	20.7
2°C Policy	1.3	8.0	12.2	21.5
1.5°C Policy	1.6	8.1	12.2	21.9

Optimal Policy 2°C Policy 1.5°C Policy

(b) Consumption gains (RE scenario vs base scenario)

Fig. 4.7 GDP gains and consumption gains (2010 $ trillion) in 2015–2065, 2065–2115, 2115–2165, and 2015–2165 (RE scenario vs base scenario). *GDP* gross domestic product, *RE* renewable energy. *Source* Authors' calculations

results show that the output allocation is toward to the capital goods sector under the optimal abatement policy from 2020 to 2085 when policy makers consider R&D investments in energy efficiency. With the 2 °C policy scenario, the output allocation is toward the capital goods sector from 2020 to 2060, and from 2070 to 2080, while it is toward the consumption goods sector from 2060 to 2070, and from 2080 to 2100. With the 1.5 °C policy scenario, the output allocation is toward the capital goods sector from 2020 to 2040 and from 2045 to 2070, while it is toward the consumption goods sector from 2040 to 2045 and from 2070 to 2100. The downward spikes are due to the energy substitution of fossil fuels by renewable technology. It means more output should be allocated to the capital goods sector to support R&D investments in energy efficiency before the energy use pattern transits from fossil fuels to renewable energy.

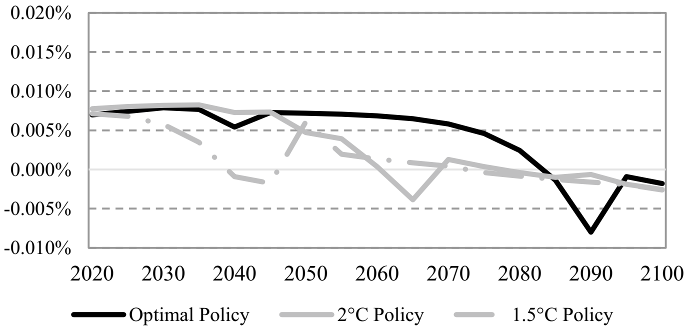


Fig. 4.8 Percentage change in the share of capital goods sector in output (RE scenario vs base scenario). *RE* renewable energy. *Source* Authors' calculations

R&D investments in energy efficiency also have an impact on the carbon tax. The carbon tax is calculated by the shadow price of the carbon-emissions equation divided by the shadow price of the capital equation. Figure 4.9 shows how much R&D investments in energy efficiency affect the carbon tax. R&D investments in energy-saving technology reduce carbon tax from 2020 to 2070 and then drive up carbon tax from 2070 to 2100 under the optimal abatement policy. They drive the carbon tax down from 2020 to 2090 and then raise carbon tax from 2090 to 2100 under the 2 °C policy scenario. R&D investments in energy efficiency lower carbon tax from 2020 to 2050 and boost carbon tax from 2050 to 2100 under the 1.5 °C policy scenario. The above results indicate that carbon tax experiences a decline in the short term when policy makers consider R&D in energy efficiency, while it experiences an increase in the long term. R&D investments in energy-saving technology effectively diminish the carbon tax with the 2 °C policy scenario. R&D investments in energy efficiency facilitate to reduce the negative externality caused by carbon emissions significantly under the 2 °C policy scenario.

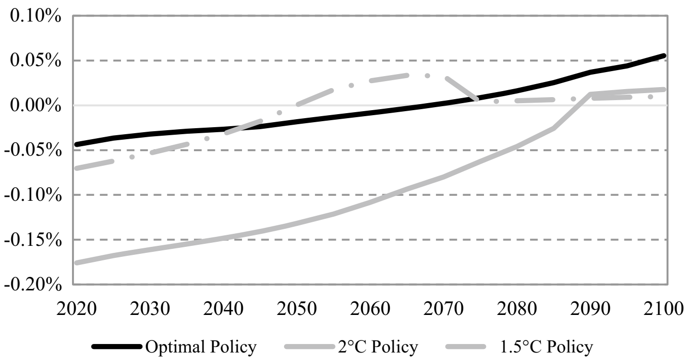


Fig. 4.9 Percentage change in the carbon tax (RE scenario vs base scenario). RE renewable energy. *Source* Authors' calculations

4.6.3 Energy Substitution, Carbon Emissions, and Climate Change

This subsection addresses several research questions regarding climate change. First, it presents the sequence of energy transition in the capital goods sector and the consumption goods sector when policy makers consider R&D investments in energy efficiency. Second, it shows the carbon emissions by 2100 when policy makers consider R&D investments in energy-saving technology. Third, it analyzes the impact of R&D investments in energy efficiency on carbon emissions. Fourth, it presents atmospheric temperature change when R&D investments in energy efficiency are taken into account.

Table 4.1 presents the energy use sequence in the capital goods sector and the consumption goods sector with R&D investments in energy efficiency taken into consideration. The energy sequence in the capital goods sector is oil, coal, and backstop technology, while that in the consumption goods sector is gas, oil, coal, and backstop technology. The backstop technology starts replacing fossil fuels in 2090 given the optimal abatement policy, in 2065 given the 2 °C policy, and in 2045 given the 1.5 °C policy. The results show that R&D investments in energy efficiency do not affect energy substitution significantly.

Figure 4.10 shows the trends in carbon emissions from 2015 to 2100. Carbon emissions climb under the optimal policy from 2015 to 2060 then decline after 2060 and eventually drop to zero in 2095. Given the 2 °C policy, carbon emissions fall slightly from 2015 to 2035, rising slightly from 2035 to 2055, and then decline after 2060, reaching zero in 2070. With the 1.5 °C policy, carbon emissions keep decreasing until they reach zero in 2055. We can decompose the reasons for the movement into two effects. First, the energy that production uses declines under a more restrictive abatement policy. Second, the energy transition to abundant fossil fuels leads to an increase in carbon emissions before the backstop technology fully replaces fossil fuels because dirty fossil fuels (e.g., coal and coal products) are more abundant than clean fossil fuels (e.g., oil and oil products). When the first effect

Table 4.1 The sequence of energy transition (optimal energy tax)

	Capital goods sector		
Optimal policy	2040 (oil to coal)	2090 (coal to backstop tech.)	
2 °C policy	2050 (oil to coal)	2065 (coal to backstop technology)	
1.5 °C policy	2045 (oil to backstop technology)		
	Consumption goods sector		
Optimal policy	2035 (gas to oil)	2045 (oil to coal)	2095 (coal to backstop technology)
2 °C policy	2040 (gas to oil)	2055 (oil to coal)	2070 (coal to backstop technology)
1.5 °C policy	2050 (oil to backstop technology)		

Source Authors' calculations

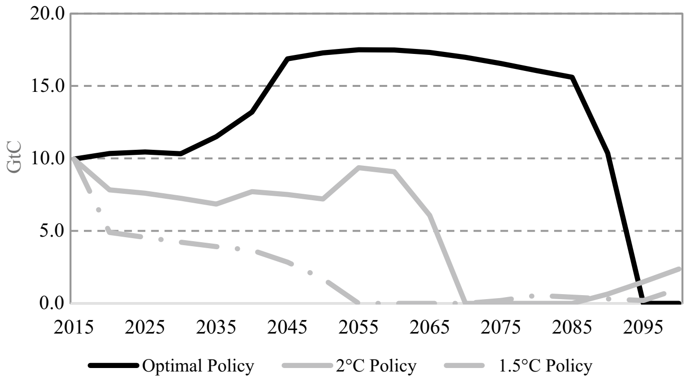


Fig. 4.10 Carbon emissions (GtC) from 2015 to 2100. *GtC* gigaton of carbon. *Source* Authors' calculations

dominates the second effect, carbon emissions increase, and vice versa. We notice that energy substitution leads to a choppy change in carbon emissions under various abatement policies. Carbon emissions become zero after the energy that production uses fully transits from fossil fuels to backstop technology. Under the 2 °C policy, production restores the use of oil after 2085, but it only accounts for a small share of the total energy use. Given the 1.5 °C policy, production reverts to the use of coal after 2075, but it only accounts for a very small share of the total energy use.

Figure 4.11 presents the slight impact of the R&D investments in energy efficiency on carbon emissions. R&D investments in energy efficiency induce higher carbon emissions in the short term while they discourage carbon emissions in the long term. The reason is that production in the capital goods sector uses more fossil fuels to create more R&D investments in energy efficiency in the short term. The increase in carbon emissions brings more R&D investments in energy-saving technology. In the long term, R&D investments in energy-saving technology

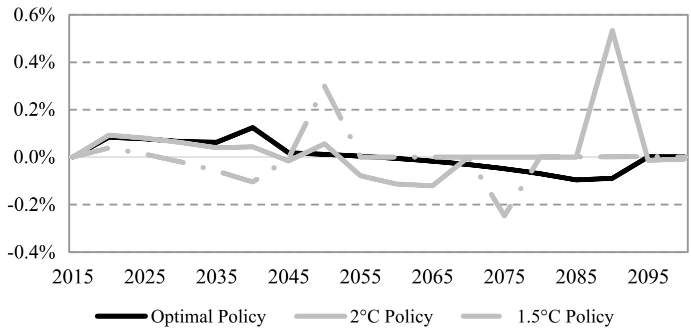


Fig. 4.11 Percentage change in carbon emissions by 2100 (RE scenario vs base scenario). *RE* renewable energy. *Source* Authors' calculations

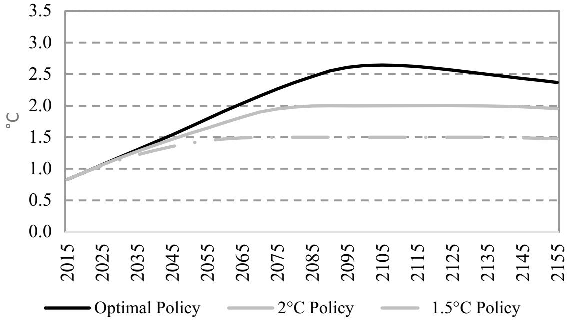


Fig. 4.12 Atmospheric temperature (°C). *Source* Authors' calculations

effectively reduce fossil fuels used in the production process and further reduce carbon emissions. Please note that the spikes in Fig. 4.11 are mostly due to energy transitions. A more stringent abatement policy leads to a fast carbon reduction while a less restrictive policy induces a delay to cut carbon emissions.

Figure 4.12 presents the atmospheric temperature given various abatement policies in the RE scenario. The highest temperature is 2.6456 °C in 2110 with the optimal policy, which is 0.6456 °C (or 1.1456 °C) higher than 2 °C (or 1.5 °C). The temperature hits the restrictive temperature level of 2 °C (or 1.5 °C) in 2090 (or 2075) given the 2 °C (or the 1.5 °C) abatement policy. The highest temperature occurs after the backstop technology substitutes fossil fuels. The delay time is about 20 years in the three abatement policies. It reflects a lagged effect of GHGs, which public policy agencies and environmental economists have observed. For example, the United States Environmental Protection Agency mentioned that carbon dioxide can stay in the atmosphere for 50 to 200 years.

4.7 Conclusion and Recommendations

This chapter explores the energy R&D investments in energy efficiency, economic welfare, carbon emissions, and climate change in a modified top-down model. First, the results provide some insights for policy makers about the amount of R&D investment in energy efficiency. Policy makers should invest in a higher amount of energy efficiency R&D in the short term if they aim at a more restrictive climate goal, such as the 1.5 °C policy. R&D investments in energy efficiency have a crowd-out effect on the R&D investments in backstop technology. A more stringent abatement policy induces a larger crowd-out effect. Policy makers appear to invest in energy R&D investments insufficiently if they overlook R&D investments in energy-saving technology. Also, they tend to underrate the share of energy R&D investments in total investments if they fail to take into account R&D investments in energy efficiency. The underrated effect is more significant for a more restrictive abatement policy in the short term. In the long term, the underrated effect seems to be close to various abatement policies.

Policy makers also need to notice the impact of R&D investments in energy efficiency on economic welfare. R&D investments in energy efficiency have a profound and long-lasting effect on GDP enhancement and consumption enhancement. The results indicate that both GDP and consumption increase when policy makers consider R&D investments in energy efficiency into the model. The gains in GDP and consumption are less significant in the short term while they are more significant in the long term. The impact of R&D investments in energy-saving technology on the above gains is more significant under a stringent abatement policy if the policy makers restrict their interests by 2100.

Policy makers also need to consider the impact of R&D investments in energy-saving technology on economic structure. R&D investments in energy efficiency slightly shift the output allocation between the capital goods sector and the consumption goods sector. R&D investments in energy efficiency improve the production in the capital goods sector in the short run while they enhance the production in the consumption goods sector in the long run under various abatement policies. R&D investments in energy-saving technology enhance consumptions earlier under a more stringent abatement policy than a less stringent abatement policy.

The chapter also provides insights for policy makers regarding carbon tax. R&D investments in energy efficiency facilitate to reduce carbon tax in the short term and drive up carbon tax in the long term. It indicates R&D investments in energy-saving technology help to soften negative externalities caused by carbon emissions in the short term. R&D investments in energy efficiency effectively drive down the carbon tax under the 2 °C policy scenario. It means that R&D investments in energy-saving technology significantly mitigate the negative externality caused by carbon emissions under the 2 °C policy scenario.

This chapter suggests that R&D investments in energy efficiency do not change the timeframe of the energy transition. The energy sequence in the capital goods sector is oil, coal, and backstop technology, while that in the consumption goods sector is gas, oil, coal, and backstop technology. The backstop technology starts substituting fossil fuels in 2090 given the optimal abatement policy, in 2065 given the 2 °C policy, and in 2045 given the 1.5 °C policy.

Policy makers should recognize that R&D investments in energy efficiency slightly affect carbon emissions although they do not change the energy sequence. R&D investments in energy efficiency bring more carbon emissions in the short term while they impede carbon emissions in the long term. A more restrictive abatement policy induces an early decline of carbon emissions while a less restrictive policy postpones the carbon reduction.

This chapter also presents the simulated atmospheric temperature given various abatement policies in the RE scenario. The atmospheric temperature will increase up to 2110, reach the highest increase in temperature at 2.6456 °C, then decline. The highest temperature occurs after the backstop technology substitutes fossil fuels. It indicates the GHGs have a time lag to affect the atmospheric temperature.

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Part II
Regional Studies

Chapter 5
Nexus of Energy Efficiency and Energy Access in ASEAN: Trends and Financing Schemes

Yang Liu and Riasat Noor

Abstract The Association of Southeast Asian Nations' (ASEAN) accelerated economic performance and projected growth in recent years requires increasing energy demands across the region. As it plans to reduce energy intensity by 20% by 2020 and 30% by 2025, it is important to realize the of energy efficiency context and optimize its use for the ASEAN energy sector which is now dubbed first fuel rather than hidden fuel or fifth fuel due to its viability in the region.

Some countries in the region, i.e., Malaysia and Thailand, are already stepping up efforts in the development of innovative financing models that combine public and private investments on energy efficiency. Based on common findings, the other countries should also adopt the mechanisms for a smooth transition toward innovative energy efficiency efforts.

The chapter has analyzed sectorial practice & challenges and policy instruments used for energy efficiency management in the ASEAN countries. It has also assessed institutional capacity, financial mechanism, and relevant cases of innovative financing schemes and energy investment mechanisms. Based on the study findings, it is suggested to develop relevant guidelines for project developers and market players specially for revising fossil fuel subsidies. An all-stakeholder contribution, especially private sector participation and an awareness raising campaign for energy investors and general public should be conducted. A transparent and accountable financing, reporting, and verification method should also be followed and successful financing schemes should be replicated in the other ASEAN member states.

Keywords ASEAN energy sector · Energy efficiency · Financing energy efficiency · Financial models

JEL Classification Q200

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5.1 Introduction

5.1.1 Background of the Study

Southeast Asia is one of the most prominent players in the global economic and energy portfolio. The Association of Southeast Asian Nations (ASEAN), as a region, was the 7th largest economy and the 5th largest investment destination in 2016. With a collective gross domestic product (GDP) of over $2.5 trillion, ASEAN is one of the largest economic blocs in the world. Strong economic growth has fueled a 70% increase in energy demand since 2000, and the region now accounts for 5% of total global energy demand. However, it is important to efficiently manage the finite energy resource to meet the infinite demand and sustain the achievements of the economic development.

In this regard, the ASEAN member states intend to cut down regional energy intensity (EI) by 20% by 2020 and 30% by 2025, compared to the 2005 level. As the region is experiencing increasing energy demand, each country will require concerted effort to meet the projected target. More specifically, ASEAN should strengthen its cooperation in effective policy development and harmonization. Most of the ASEAN states have already integrated the relevant polices in energy management, which can be replicated by the remaining countries as successful cases. These potential and momentum of collaboration in reducing energy intensity and sustaining energy efficiency (EE) is one of the greatest drivers to foster dynamic regional and economic growth in ASEAN.

Energy efficiency is the concept of improving energy productivity, measured as the inverse of energy intensity, which implies increasing economic output per unit of energy consumed. It can reduce import dependency, and result in less environmental pollution. It reduces energy consumption without compromising consumer usage or country's competitiveness. For example, 1 megawatt (MW) of power saved through EE is equivalent to about half or less than adding 1 MW of coal-fired generating capacity. EE is increasingly becoming a critical consideration for countries, especially those in the ASEAN region, as a way to promote sustainable growth in the face of fast-growing energy demand. Widely known as a low-hanging fruit, EE has recently been labelled the fifth fuel for being in effect the 'cheapest and cleanest' choice for balancing energy supply and demand for sustainable development (There are four main types of fuel sources—coal, hydrocarbon (natural gas and petroleum), nuclear, and renewable energy. Energy efficiency is considered as the fifth fuel and is the greenest and most cost-effective of the five sources). More recently, it has been termed as "first fuel" from hidden fuel in the ASEAN context (first fuel is a source of energy in its own right, in which they can invest ahead of other more complex or costly energy sources) (Martinez et al. 2019).

Some of the key trends in Southeast Asia are discussed below.

Indonesia accounts for over 35% of the region's total energy demand. Overall, fossil fuels supply around 75% of the region's energy mix, with oil taking the largest share (34%), followed by gas (22%) and coal (17%). Hydropower has grown rapidly and the deployment of solar photovoltaic and wind energy is also starting to pick up, albeit from a low base in most countries. The use of solid biomass for cooking is widespread, but it accounts for a decreasing share of primary energy use. Many ASEAN countries are taking concerted steps to address energy security and environmental concerns. To address the pressing problems with local pollution and carbon emissions, many countries are adopting revamped policy dimensions to reduce EI and speed up the deployment of RE.

5.2 Literature Review

5.2.1 Nexus of Energy Access and Energy Efficiency in the Context of ASEAN

Southeast Asia plays an increasingly important role in the future global energy landscape. Today, ASEAN is projected to be the fourth largest economy in the world by 2030. The population is set to rise by more than 10% to 690 million by 2020. Energy is essential to underpin this economic growth. Investments in power generation capacity and infrastructure will be needed to meet ASEAN's energy demand, which has grown by 60% over the past 15 years. The International Energy Agency estimates that the investments will continue to grow by another two-thirds by 2040.

Strong economic growth and rising population have fuelled an increase by a factor of 4.5 in the total final energy demand over the period from 1971 to 2015. To meet this increasing energy demand, energy efficiency is vital to improving energy access in the region. Of the 625 million people living in Southeast Asia (10% of the toal population), about 125 million lack of access to stable electricity and 40% of the ASEAN population primarily rely on traditional use of biomass. In countries such as Indonesia and Philippines, it is a major challenge to provide electricity to communities living on remote islands, and geographical factors make it difficult to connect macro-grids. Global Climate Scope expects Southeast Asia to spend $14 billion to reach universal access to electricity by 2030, with 75% of off-grid population mostly served through remote micro-grid systems where both the supply and demand sides of energy efficiency have a crucial role to play in increasing the available bandwidth in existing generation, transmission, and distribution networks (Brasington 2018).

It has been shown that a 1–4% investment in energy efficiency as a share of overall energy sector investment, can meet as much as 25% of the projected increase in primary energy consumption in developing Asian countries by 2030. This cost-effective investment, in turn, can boost regional energy security by tempering the need for imported energy, as most countries in the region, 2 decades from now, will produce 50% or less of the energy they require (ADB 2013).

5.2.2 Growing Challenges of Future Energy Demand in ASEAN

Total final energy consumption (TFC) per capita in ASEAN has grown significantly from 530.9 kilotons of oil equivalent (Ktoe) to 721.7 Ktoe from 2000 to 2016. In the same period, per capita energy consumption in the residential sector declined by 0.3%, but this was offset by a 63.3% growth in the transport sector (Fig. 5.1). Although six of the ten economies are net energy exporters today, many of them will not be able to sustain self-sufficiency over the next decade, as energy use tends to surpass domestic energy production quickly. It is thus important to manage energy demand growth to ensure energy security and sustainable development.

However, energy efficiency has different implications and dimensions in ASEAN because of great intraregional economic disparity. Using taxonomy from the United Nations Development Program, in 2014, Brunei Darussalam and Singapore were classified as countries of "very high human development"; Thailand and Malaysia fell into the category "high human development"; Cambodia, Indonesia, the Lao People's Democratic Republic, the Philippines, and Viet Nam were countries of "medium human development"; while Myanmar was classified as a country of "low human development". Within these broad categories, there were also large variations in the precise level of development a country has achieved, as reflected through disparities in the human developent index rank and value. Table 5.1 displays each ASEAN member state's level of development next to its energy consumption. As illustrated in Table 5.1, energy consumption is strongly positively correlated with development.

The relationship between economic growth and energy consumption is important to note as it shows that a country can undergo different stages of structural change in its energy system as it develops economically. Therefore, we discover three energy transition processesreflected by energy intensity trends in ASEAN. We

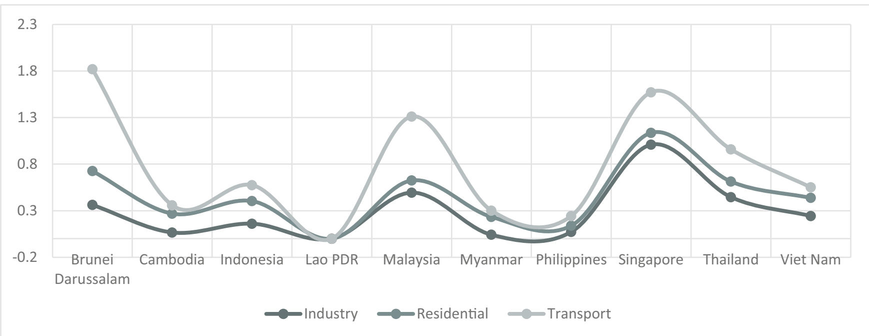

Fig. 5.1 Trends in total final consumption for industry, residential, and transport sectors (2015) *Lao PDR* Lao People's Democratic Republic. *Source* Authors' customized work from different sources (IEA and World Bank datasets)

Table 5.1 Data on the development and energy use of ASEAN member states (2014)

ASEAN member state	HDI rank	HDI value	Energy use (kg of oil equivalent per capita)
Very high human development			
Singapore	11	0.912	5,122
Brunei Darussalam	31	0.856	8,632
High human development			
Malaysia	62	0.779	2,968
Thailand	93	0.726	1,970
Medium human development			
Indonesia	110	0.927	884
Philippines	115	0.668	476
Viet Nam	116	0.666	655 (2013)
Lao People's Democratic Republic	141	0.575	Data not available
Cambodia	143	0.555	417
Low human development			
Myanmar	148	0.536	293

HDI human development index, *kg* kilogram. *Source* IEA (2018)

can further theoretically establish a causal relationship between economic growth and energy consumption.

Households in countries classified in the low human development and the lower end of the medium human development categories, due to high rates of poverty, are less able to afford the use of electricity or alternative energy sources. These factors contribute to the low energy use of these countries, since many of their residents are excluded from energy consumption.

Countries classified in the higher end of the medium human development and in the high human development categories are in the process of transitioning to higher energy consumption, due to their greater wealth. Additionally, the process through which they develop necessitates higher energy consumption due to the installation of manufacturing and processing systems, as well as the construction of new facilities to attract investment. To stimulate economic growth, Thailand has invested in numerous large-scale infrastructure development projects like roads to facilitate trade by improving connectivity in the Greater Mekong Subregion. The Indonesian government, in 2015, also embarked on an extensive infrastructure improvement plan to boost foreign investment.

Countries in the very high human development category exhibit high rates of energy consumption, as their populations are generally able to purchase high amounts of energy. As these populations are also accustomed to and desire a high standard of living, they also demand higher energy consumption to support access to a multiplicity of services and goods.

To further address the role of EE in fast growing energy demand in the context of ASEAN countries in the medium development level, cases from Cambodia are discussed in Sect. 5.4.4. As Cambodia has demonstrated practical and replicable strategies in mitigating the energy crisis, the roles models can be applied to other medium and lower development countries.

5.3 Energy Efficiency in ASEAN

5.3.1 Trends in ASEAN

From the previous section, the relationship between economic growth and energy use is further illustrated through Fig. 5.2, a scatterplot that charts the different relationships between TFC per capita and GDP per capita for six ASEAN countries: Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam. The People's Republic of China (PRC) is used as a benchmark as its economic growth

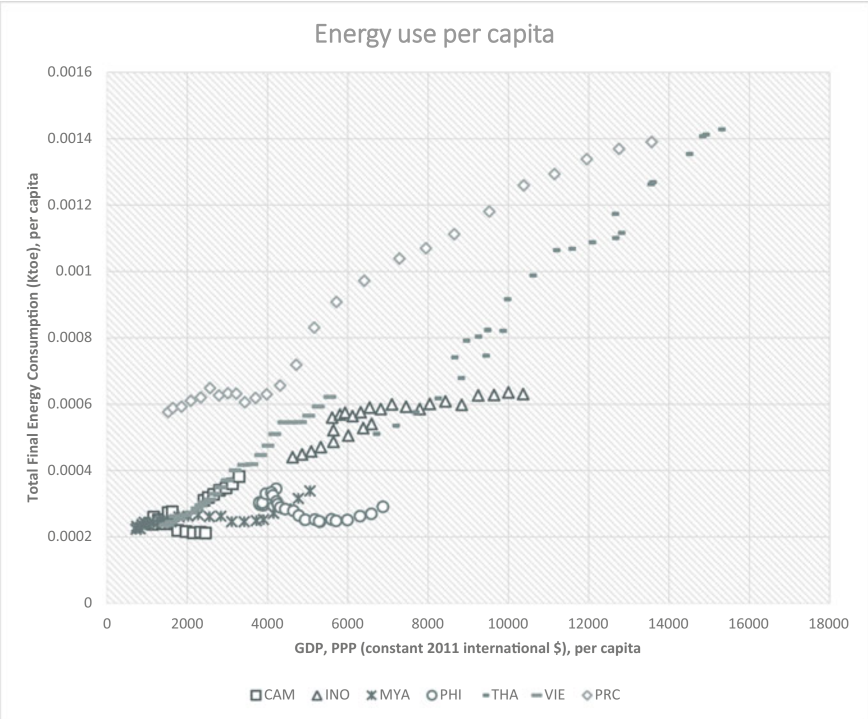

Fig. 5.2 Energy use per capita. *GDP* gross domestic product, *CAM* Cambodia, *INO* Indonesia, *Ktoe* kiloton of oil equivalent, *MYA* Myanmar, *PHI* Philippines, PPP purchasing power parity, *PRC* People's Republic of China, *THA* Thailand, *VIE* Viet Nam. *Source* Authors' customized work from different sources (IEA and World Bank dataset)

occurred in the same time frame and at the same rate as that of the fastest growing ASEAN economies.

Beyond illustrating a general relationship between GDP per capita and TFC per capita, Fig. 5.2 provides notable details of energy growth trends in ASEAN.

First, at present, TFC per capita in Thailand is surpassing that in the PRC and expanding quickly. Thailand's current income per capita of $15,000 exceeds that of the PRC and is on par with that of the Republic of Korea in 1989 and Japan in 1968. From a simple linear regression performed on data from 2007 to 2015, a 1% change in Thailand's GDP was associated with a 1.308% change in its TFC. Should all other states in ASEAN follow Thailand's trajectory while economically growing at the same rate as they did from 2007 to 2015, energy consumption will be approximately 1,228 million tons of oil equivalent in 2030, an increase of 783 million tons of oil equivalent. The slopes of the curves for Viet Nam and Cambodia already show the same upward trend as Thailand's, and TFC per capita in Viet Nam is the highest at the same level of GDP per capita across ASEAN.

Second, while the relationship between TFC and GDP per capita is linear for most countries in Fig. 5.2, those for Myanmar and the Philippines are U-shaped, and likely announces the beginning of exponential growth. Increases in energy consumption are likely to sharpen accompanying increases in GDP in these two countries. Myanmar and the Philippines therefore need to investigate and implement effective policies to reduce energy intensity.

Third, from Fig. 5.2, Cambodia, Viet Nam, and Thailand experienced the highest rise in TFC relative to GDP per capita, whereas Indonesia, Myanmar, and the Philippines experienced much more modest increases in TFC per capita. How can this difference be explained?

We first examine whether this difference can be explained through variation in economic structures. Conventional wisdom that aims to explain the relationship between economic growth and energy consumption posits that energy consumption is intimately related to the economic structure of a country. Considering that development theory argues that the economic structure of a country is linked to its development phase, since countries transition from specializing in agriculture to industrial economies and finally to tertiary and quartenary services-based economies, it would therefore follow that economic growth is related to energy consumption. This would suggest that economic structure, not economic growth, is the primary factor that influences energy consumption, considering that it is the intervening variable through which economic growth results in higher energy consumption. Presumably, a country's energy consumption depends on its economic structure as industrial processes are highly energy-intensive relative to agricultural processes and the provision of services (Abbas et al. 2018).

However, a closer look at data on the economic structures of the ASEAN member states will inform us that the different economic structures is not a key explanatory factor for the differences in rates of increase in energy consumption alongside economic growth.

As shown in Fig. 5.3, Indonesia and the Philippines have similar economic structures that were largely static between 1990 and 2015. However, compared to

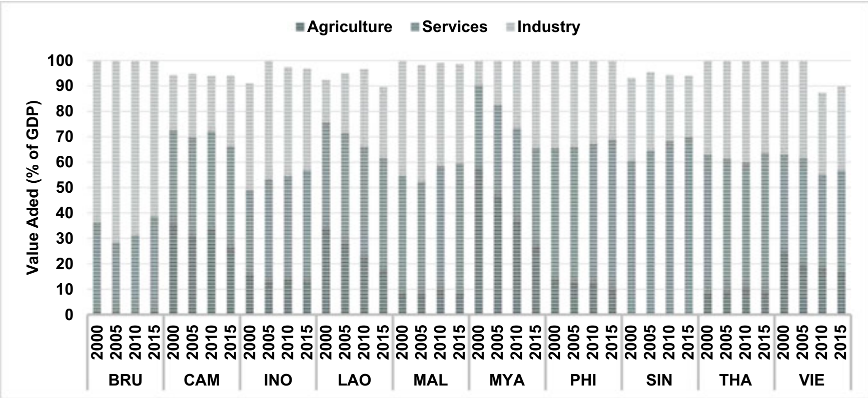

Fig. 5.3 Economic structure of different ASEAN member states (2000–2015). *ASEAN* Association of Southeast Asian Nations, *BRU* Brunei Darussalam, *CAM* Cambodia, *GDP* gross domestic product, *INO* Indonesia, *Ktoe* kiloton of oil equivalent, *LAO* Lao People's Democratic Republic, *MAL* Malaysia, *MYA* Myanmar, *PHI* Philippines, *SIN* Singapore, *THA* Thailand, *VIE* Viet Nam. *Source* Authors' customized work from different sources (IEA and World Bank dataset)

the Philippines, Indonesia's energy consumption per capita rose more dramatically as its GDP per capita rose. At the same time, while Viet Nam and Thailand have different economic structures, as Thailand has a larger services sector, and Viet Nam's economy is more agriculture-based, their energy consumption trajectories in Fig. 5.3 are similar.

An examination of more data regarding the characteristics of these countries would lead us to conclude that perhaps differences in electrification rates is a main determinant of energy consumption in the ASEAN region. Thailand and Viet Nam, on the other hand, have the highest electrification rates, as shown in Fig. 5.4, which could explain their comparatively higher rates of energy consumption relative to GDP. However, Cambodia is still anomalous, as it has the lowest electrification rate, but has the highest TFC per capita when compared to Myanmar and the Philippines, countries in which residents have greater access to electricity.

With respect to EI reduction trends, as shown in Fig. 5.4, EI levels experienced the most rapid rate of decline in the least developed countries in ASEAN, Cambodia and Myanmar, even in the virtual absence of energy efficiency policies. This appears counter-intuitive, but may be explained by the transition from the use of traditional biomass-based energy like straw, firewood and coal to traditional commercial energy like liquefied petroleum gas, electricity, and solar energy. Accompanying this transition was a marked reduction of energy consumption per capita that led to a significant improvement in energy intensity.

Electrification rates therefore do not completely explain energy trends in ASEAN: while higher electrification rates may mean higher energy consumption, in the early stages of electrification, it also may mean a concerted government effort to switch from inefficient means of energy production to more efficient methods.

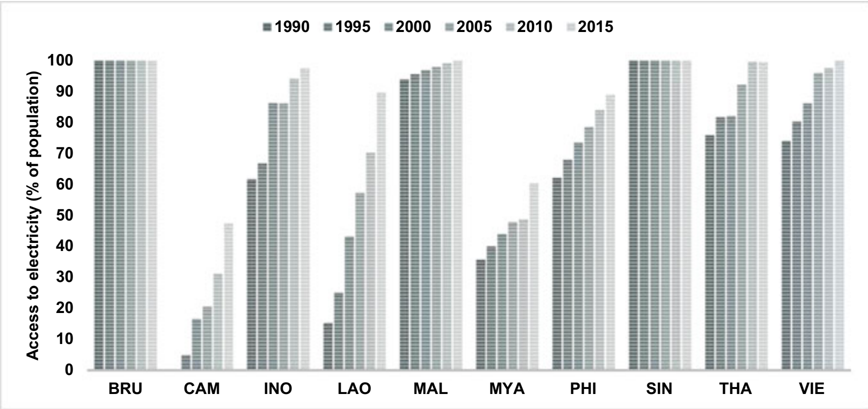

Fig. 5.4 Electrification growth among ASEAN member states (1990–2015). *ASEAN* Association of Southeast Asian Nations, *BRU* Brunei Darussalam, *CAM* Cambodia, *INO* Indonesia, *Ktoe* kilotons of oil equivalent, *LAO* Lao People's Democratic Republic, *MAL* Malaysia, *MYA* Myanmar, *PHI* Philippines, *SIN* Singapore, *THA* Thailand, *VIE* Viet Nam. *Source* Authors' customized work from different sources (IEA and World Bank dataset)

Energy consumption per capita may therefore follow a U-shaped curve when plotted against electrification rates. Indeed, Viet Nam and Thailand, which exhibit the highest electrification rates and electrification growth, also experience strongest growth in TFC relative to GDP, whereas Indonesia and the Philippines, which have experienced slower rates of growth in electricity access, have flatter TFC relative to GDP slopes. This also explains the anomalous result described earlier: Cambodia is still in an early stage of transition to more energy-efficient sources, which is why its EI remains high as electricity consumption outstrips the rate of increase in energy efficiency. However, EI in Cambodia has been falling over the past years, and as Cambodia continues on its electrification path, the TFC per capita relative to GDP will likely fall more rapidly.

To summarize the energy transition stages, with increasing income, households and industries in ASEAN member states adopt more advanced commercial energy as substitutes for traditional energy. This is in adherence to the energy ladder hypothesis, a concept attributable to Hosier and Dowd (1987), whose paper was one of the first to discuss the relationship between economic development and type of fuel predominantly used. The hypothesis states that as national income rises, a country consumes more energy-efficient fuels that can be said to occupy higher rungs on the energy ladder. Indeed, a core energy transition process that emerging ASEAN countries is undergoing is the switch from low-efficiency to high-efficiency fuels. Offsetting this reduction in energy intensity is the increased consumption of energy resulting from the rising affluence of a country. With growing income and improving living standards, the population will access more energy-consuming products and services, and the economic production of the country may be dominated by energy-intensive activities. This increases energy intensity, explaining the flat trends of EI in Thailand, Malaysia, and Brunei Darussalam.

5.3.2 Energy Targets

Moving beyond energy trends to look at concrete actions states have taken or intend to take, to ensure enduring progress in energy efficiency, in 2015, the ASEAN Plan of Action for Energy Cooperation (APAEC) designated collective energy targets for all member states (ACE 2015). These targets included a 20% reduction in EI by 2020 and a 30% reduction by 2025 based on 2005 levels, as well as a 23% RE share in total primary energy supply (TPES) by 2025.

ASEAN is on track to meet its collective EI reduction targets, and in good stead to achieve a more sustainable and secure future. By 2016, ASEAN had already accomplished a 21.9% EI reduction, exceeding its target for 2020. At the signing of a memorandum of understanding between ASEAN ministers and the International Renewable Energy Association in October 2018, this achievement was extolled by the ministers as a sign of progress and an augury of future success in energy conservation. While it is a positive signal, it also raises questions about whether APAEC set targets that were unmeaningful.

To demonstrate how APAEC may benefit from setting more ambitious targets, if we take the differential between APAEC's 2020 and 2025 EI reduction targets—5% every 5 years—to be indicative of the trajectory APAEC seeks to achieve, then its 2035 goal is likely to only stand at 40%. This target is short of the Asia–Pacific Economic Cooperation's (APEC) aggregate 2035 EI reduction target, 45%. Perhaps this difference is qualified by the economic disparity between ASEAN and APEC states, since APEC has a higher average GDP per capita. However, if we assume that states within ASEAN continue to reduce EI at a constant rate of approximately 2% per year until 2030, which is the average from 2005 to 2016, this will amount to almost a 30% reduction in EI by 2020, and an estimated 50% reduction by 2030. This means ASEAN will be able to achieve its 2025 target 5 years ahead of schedule. Given the positive showing ASEAN has demonstrated in the past, higher targets may be in order to encourage governments to serially intervene in their domestic markets to promote energy efficiency.

The gradated targets may also estimate EI reduction rates too conservatively, considering that it is likely that the growth rate in EI reduction is exponential, instead of linear across time. As governments implement robust energy policies and endorse financial instruments related to energy efficiency, entire ecosystems develop around sustainable energy in these countries. A stronger focus on energy efficiency, more opportunities for new entrants and greater competitiveness in the market will result in a virtuous cycle such that annual EI reduction rates are likely to exhibit tremendous growth. APAEC may consider adjusting its future targets to become even more aspirational, such that ASEAN member states remain active in their pursuit of domestic EI reductions that exceed business-as-usual rates.

Sharper reductions in EI are desirable even though ASEAN has discharged its responsibility to become more energy efficient and sustainable, because progressively higher EI reduction rates yield benefits to economic growth. First, higher energy efficiency reduces the expenditure each ASEAN member state allocates to energy, relative to its GDP. Second, the zealous implementation of energy policies may result in higher rates of research and development in the energy sector, potentially breeding innovations in energy efficiency. ASEAN states then can capitalise on opportunities in the greenifying global market. Additionally, as ASEAN member states experience economic growth, energy demand in ASEAN rises. Without an accompanying increase in energy efficiency that overwhelms and offsets the growth in energy demand, the TFC in ASEAN will continue to grow. Although the current EI reduction trend, if it does not abate, will mitigate some of the environmental impact of energy demand increases in the future, it will be insufficient to completely eliminate the prospect of more damage wrought on the enviroment.

Beyond the aggregate targets, ASEAN member states have also specified energy efficiency targets for their own countries to which to aspire.

While the establishment of national-level targets implies that each member state is committed to increasing energy efficiency in the region, the diversity apparent in these targets may jeopardize regional cooperation to increase energy efficiency. Across ASEAN, each country has created its own timeline and demarcated its national areas of focus. Such specificity allows countries to nuance targets to their own unique characteristics and interests but may result in negative spillover effects on other states that result from uncoordinated policy action.

There are a few more problems with the designated targets. First, each ASEAN member state has multiple timelines for their targets ranging from near and medium term (2020–2025) to long term (2035). Second, the targets specify multiple emissions-intensive sectors (electricity, commercial, transport, industrial etc.) and renewable energy sources (solar, wind, biomass etc.). Third, the energy efficiency targets vary in terms of energy-related indicators on the supply-side (TPES, installed electricity capacity) and demand-side (TFEC, electricity consumption). Fourth, only half the ASEAN member states have committed to a national GHG emissions target in their nationally determined contributions. Finally, and most critically, all the targets are specified in relative terms (as per GDP or a year-wise baseline) and not as absolute values.

5.3.3 Investment in Energy Efficiency

Driven by massive industrial growth, energy demand in Asia and the Pacific is projected to be more than double between 2010 and 2035, reaching more than

16,169 terawatt hours (TWh) in 2035. Unless any alternative measure is taken, the region will need investment of approximately $11.7 trillion in the power and energy sector. The investments required for the same MW is about 1.8 times on the average compared to fossil fuel technology.

Table 5.2 shows energy capacity assessment and required investment in 2016–2025 for the ASEAN member states:

Figure 5.5 shows the impact of investment in EE on meeting energy demand by 2030, assuming that national EE targets are met. In Brunei Darussalam, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, an EE investment share of just 1% to 4% of overall energy investment serves to meet at least 8% to as much as 25% of the projected increase in primary energy consumption. This dynamic reinforces EE's relevance as a least-cost solution to meeting Southeast Asia's growing energy demand.

Table 5.2 Needs assessment and investment required in 2016–2025

ASEAN economy	Capacity/Needs assessment	Required investment ($ million)
Brunei Darussalam	NA	48
Cambodia	NA	126
Indonesia	56 GW of additional capacity is required according to RUPTL 2018–2027 (PWC Indonesia 2018)	6,019
Lao People's Democratic Republic	NA	29
Malaysia	NA	901
Myanmar	Myanmar has massive demand for power. However, most government policies do not cover any investor interest	165
Philippines	NA	601
Singapore	Overcapacity in Singapore with Malaysia unlikely to require much additional capacity	97
Thailand	Overcapacity in Thailand with Malaysia unlikely to require much additional capacity	2,006
Viet Nam	Additional 90 GW of new IPP capacity to be required by Viet Nam by 2030	649
ASEAN total		10,641

ASEAN Association of Southeast Asian Nations, *GW* gigawatt, *IPP* independent power producer, *NA* not available, *RUPTL* Rencana Umum Penyediaan Tenaga Listrik. *Sources* IIEC (2017), ADB calculations based on national EE targets (ADB 2013)

	EE Investment Out of Total Energy Sector Investments (%)	Projected Primary Energy Consumption Met through EE (%)
Brunei Darussalam	0.4 %	20%
Indonesia	4%	25%
Malaysia	1%	21%
Philippines	1%	8%
Thailand	4%	22%
Viet Nam	1%	8%
Legend	EE Investments Total Energy Sector Investments	Share Met by EE Total Projected Primary Energy Consumption
Notes	1. Some percentages reflect rounding 2. Projected impacts of EE investment by 2030 assume national EE targets are met.	

Fig. 5.5 Energy efficiency in projected energy investments and primary energy consumption in Southeast Asia. *Notes* Some percentages reflect rounding. Projects impacts of EE investment by 2030 assume national EE targets are met. *EE* energy efficiency. *Source* Data from Asian Development Bank with the Institute of Energy Economics, Japan (2009)

5.4 Financing Schemes for Energy Efficiency

5.4.1 Energy Efficiency and Conservation Institutional and Policy Framework at the ASEAN Level

Improving energy efficiency has been identified as the region's top priorities to achieve energy security, accessibility, affordability and sustainability. All countries in the region have adopted EE policies and programs to achieve energy savings across different sectors. Most ASEAN member states have enacted a series of laws, acts or regulations, set up priorities for energy conservation, and assigned functions or created agencies with the mandate to develop strategies and mechanisms to promote energy efficiency and conservation (EE&C) by establishing ASEAN member states' specific energy saving targets (Table 5.3).

Table 5.3 Policy framework and EE targets in ASEAN member states

Country	Reference documents	EE targets of ASEAN member states
ASEAN region	APAEC (2016–2025)	20% Reduction in energy intensity (EI) by 2020 and 30% by 2025 with a 2005 baseline
Brunei Darussalam	Energy White Paper 2014	Reduce TFEC by 63% and energy intensity by 45% in 2035 (based on 2005 level)
Cambodia	Cambodia EE Plan	Reduce TFEC by 20% in 2035 (BAU)
Indonesia	National Energy Policy (Government Regulation No. 79/2014)	• Reduce TFEC in 2025 by 17% in industry, 20% in transportation, 15% in household, 15% in commercial building (BAU) • Achieve 1% energy intensity reduction per year until 2025 and energy elasticity of less than 1 in 2025
Lao People's Democratic Republic	National EE Policy 2016	Reduce TFEC by 10% in 2030 (BAU)
Malaysia	National EE Action Plan	Reduce electricity consumption in TFEC by 8% in 2025 (BAU)
Myanmar	National EE&C Policy	Reduce electricity consumption in TFEC by 20% in 2030 (BAU)
Philippines	EE Roadmap for the Philippines, 2017–2020	• Reduce TFEC by 1% per year until 2040 (BAU), equivalent with the reduction of 1/3 of energy demand • Reduce energy intensity by 40% in 2040 (based on 2005 level)
Singapore	Sustainable Singapore Blueprint 2015	• Reduce energy intensity by 35% in 2030 (based on 2005 level)
Thailand	Energy Efficiency Plan (EEP 2015)	• Reduce energy intensity by 30% in 2036 (based on 2010 level)
Viet Nam	National Target Program for EE&C	• Reduce TFEC by 8% in 2020 (BAU) • Reduce energy intensity of energy intensive industries by 10% in 2020

APAEC ASEAN Plan of Action for Energy Cooperation, ASEAN *Association of Southeast Asian Nations, BAU* business-as-usual, *EE* energy efficiency, EE&C energy efficiency and conservation *TFEC* total final energy consumption. *Sources* ERIA (2016), ACE (2017a)

5.4.2 Financing Schemes and Instruments for Energy Efficiency and Conservation Projects Used in ASEAN

Countries such as Indonesia, Malaysia, Singapore, Thailand, and Viet Nam have been able to develop more advanced frameworks by creating dedicated schemes to finance EE&C. Thailand, for example, developed the Energy Efficiency Revolving Fund (EERF), which allows the private sector to access dedicated funds that are repaid when projects become operational. Likewise, Malaysia has developed the Energy Performance Contracting Fund (EPCF), which uses government guarantees to make projects more bankable and attractive to investors. Malaysia has also implemented the Sustainability Achieved via Energy Efficiency (SAVE) program, which uses rebates as a cost-effective mechanism to promote the adoption of efficient technologies within households.

Singapore has various financial schemes to finance EE projects such as the Energy Efficiency Fund (E2F) for the industrial sector and the Green Mark Incentives Schemes for the building sector. Indonesia developed various schemes including an Infrastructure Fund and Viability Gap Fund (VGF). In Viet Nam, financing schemes from the Vietnam Environment Protection Fund (VEPF), the National Technology Innovation Fund (NATIF), and the Vietnam Development Bank can also be used to finance EE&C projects. Each of the initiatives above is addressed in Sect. 5.3 of this chapter (Fig. 5.6).

5.4.3 Types of Energy Efficiency and Conservation Financing Required for ASEAN

EE financing can be grouped into two main types: traditional financing and emerging (or specialized) instruments. Traditional financing instruments (e.g., loans and leases) are commonly used to pay for EE initiatives as well as other goods and services. Emerging or specialized instruments are specifically designed to support EE activities and other clean energy installations and to overcome market barriers.

Although policy makers and development banks are familiar with traditional financing instruments, due to multiple challenges, these instruments cannot always be applied. The challenges include the lack of financial and technical capacities, both from the demand and supply side, the lack of interest from potential project developers, the absence of policy frameworks that encourage investment in EE&C projects, and others (Rugova 2016). To address such aspects, further innovative financing instruments such as PACE and on-bill repayment are emerging mostly in developed countries (e.g., in Europe and North America) with the aim to address some of the investment hurdles (ACE 2019).

Following are some of the proven methods which can be opted for harnessing better energy efficiency in the region (ADB 2013).

ASEAN-wide Projects

ASEAN Energy Management System (AEMAS) Training and certification of energy managers from various companies	**ASEAN-Japan Energy Efficiency Partnership (AJEEP)** Cooperation between Japan and ASEAN in information sharing and opportunity creation	**ASEAN Standard Harminization Initiative for Energy Efficiency (ASEAN Shine)** Increase energy efficiency of air conditioners through harminizing standards
ASEAN+3 Mitigation Cooperation Program Competition with the Republic of Korea inexpertise pooling on GHG reduction	**Energy Conservation Workshop under AJEEP (ECAP)** Cooperation with Japan in hosting a training session on energy conservation	**Energy Efficiency Market Transformation with Information Provision Scheme (EMTIPS)** Providing information to consumers

Energy Efficiency

Policy	BRU	CAM	INO	LAO	MAL	MYA	PHI	SIN	THA	VIE
Energy Labelling	√	√	√	√	√	√	√	√	√	√
Incentives	√	√	√	×	√	×	√	√	√	√
Tariff Reform	√	×	√	×	√	√	×	√	√	√
Dedicated EE Grants			√	√	√		√	√	√	√
Dedicated EE Loans					√	√		√	√	
Dedicated EE Equity									√	
Dedicated EE Guarantee					√	√				
Others					EPC, rebates					

Renewable Energy

Policy	BRU	CAM	INO	LAO	MAL	MYA	PHI	SIN	THA	VIE
Feed-in-Tariffs	×	×	√	√	√	×	√	√	√	√
Incentives	×	×	√	√	√	×	√	√	√	√
Financing Support	×	√	√	√	√	×	√	√	√	√
Permits and Licenses	×	√	√	√	√	×	√	√	√	√
Technical Aspects	×	√	√	√	×	√	√	√	√	√

Fig. 5.6 Energy efficiency policies in ASEAN member states. *ASEAN* Association of Southeast Asian Nations, *BRU* Brunei Darussalam, CAM Cambodia, *EE* energy efficiency, *EPC* energy performance contracting, *INO* Indonesia, *LAO* Lao People's Democratic Republic, *MAL* Malaysia, *MYA* Myanmar, *PHI* Philippines, *SIN* Singapore, *THA* Thailand, *VIE* Viet Nam. *Sources* ERIA (2016), IEA (2018)

- **Utility (Electric or Gas) Financing**. Options entail utility bill financing, subsidies, or other financing assistance.
- **Special Purpose Funds.** These funds have been put to use in a variety of ways, and typically are created by donor agencies, governments, or regulators.
- **Performance Contracting.** Energy service company (ESCO)-type approaches can be undertaken by private or public sector actors.

Table 5.4 Traditional and emerging (specialized) financing instruments

Traditional financing instruments (for portraying the importance of EE&C financing)	Specialized financing instrument (to enable EE&C investments at scale and depth)
Debt, including dedicated credit lines (soft loans)	Payment security schemes, e.g., on-bill repayment, On-tax finance, PACE
Grants, e.g., project development	Crowdfunding
Leasing	Results-based financing (RBF)/carbon financing
Infrastructure, EE, and revolving funds; risk sharing facilities	Asset-backed securities (ABS) and revenue bonds
Energy performance contracting (EPC), energy service companies (ESCOs), energy service agreements (ESA)	Green bonds
Traditional guarantees and insurance	New guarantees and insurance, e.g., energy savings insurance (ESI)
Equity e.g., venture capital (VC)	

EE energy efficiency, *EE&C* energy efficiency and conservation. *Source* Authors' customized compilation from different sources

- **Equity funds**. These types of funds may come from public sector agencies or private sector venture capital firms to support investment in ESCO projects, serving as a form of "last mile" equity investment.
- **Dedicated Credit Lines.** These are typically funds made available to local banks and financial institutions by donor agencies, to expand accessible funding for investment in EE projects. The goal is often to leverage these funds by additional resources from participating financial institutions and banks.
- **Credit Guarantee Mechanisms.** These may be provided as part of risk-sharing programs, to lower the risk of EE project financing for participating financial institutions and banks.

More specifically, we can divide the instruments into traditional and emerging (specialized) financing instruments which are shown in Table 5.4:

5.4.4 Replicability of Innovative Financial Schemes

Following are some of the innovative financial schemes for the energy efficiency sector in the ASEAN member states. These schemes are presented here for their lucrativeness and high scope for replication in both public and private sectors of other countries.

ResponsAbility Scheme & PRASAC (Cambodia)

PRASAC, a leading microfinance institution in Cambodia, received $20 million from the energy efficiency lending facility, ResponsAbility a fund focused on climate financing. Launched in 2016, the PRASAC and ResponsAbility green lending

Table 5.5 PRASAC intervention in Cambodia

Group loan	Up to $500 per group member	Green financing	Energy Efficiency and Renewable Energy
Loan for biogas plants	8,411 plants amounting over $5 million	Loans for efficient tractors and power tillers	More than $7 million to 529 borrowers
CO_2 emissions reduction	1,500 tons/year or equivalent to 429,700 L of diesel/year		

Source PRASAC (2018)

program aims to offer financing in the areas of energy efficiency. The funding enables PRASAC to offer loans that improve energy efficiency for the use of low-income households and farmers. Currently, PRASAC offers loans to farmers in Cambodia to purchase tractors or tillers that are verified to meet 20% energy-saving criteria (Table 5.5 and Fig. 5.7).

Success

- The dedicated energy-efficient tractor and tiller loans enable rural farmers use of an energy efficient product that reduces GHG emissions and business operating costs.

Replicability

- To extend to other sectors, PRASAC would need to design a new loan for specific technologies that meets PRASAC and ResponsAbility eligibility criteria and local market demand while proves that the product demand will be both sustainable and profitable.

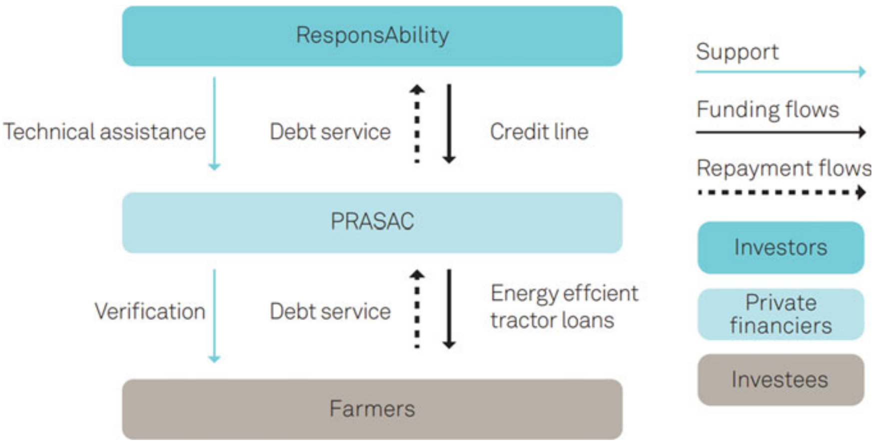

Fig. 5.7 ResponsAbility scheme and PRASAC framework. *Source* Nexus for Development (2019a, b)

Nexus for Development: The Clean Energy Revolving Fund and the Pioneer Facility (Cambodia)

Nexus for Development manages the Clean Energy Revolving Fund (CERF) to provide uncollateralized loans to small and medium-sized farms, so they can switch to clean energy technology. The fund works closely with local solar energy technology distributors and mainly supports solar water pumps and on-grid solar systems for fruit, spice, and livestock farms in Cambodia (Table 5.6).

The Pioneer Facility provides affordable uncollateralized working capital loans to social enterprises selling clean energy and water technologies that benefit low-income populations in Southeast Asia. In addition to financing, Nexus supports the funded enterprises through technical assistance. By providing debt funding to Khmer Water Supply Holding, a social enterprise that greatly increases access to clean, the initiative has already connected over 13,000 households to piped water and has a long-term plan to provide clean water to over 60,000 households and 300,000 individuals. It is also planning to directly finance the acquisition of two additional piped water stations with a combined connectivity potential of approximately 12,500 households in Cambodia (Nexus for Development 2019a, b) (Fig. 5.8).

Successes

- The CERF provides loans to agri-businesses in Cambodia to reduce their carbon footprint and save operating costs as clean energy technology utilize natural and more cost-effective energy resources such as solar energy. Although financial literacy among farmers is generally low, the loan portfolio of the CERF has been performing well with only one default of payment recorded so far.

Replicability

- Extend to other Southeast Asian countries: Nexus is assessing the potential replicability of the CERF in Myanmar.

Table 5.6 CERF intervention in Cambodia

Number of loans provided	15	Loan size	\$7,000 to over \$50,000 Mostly in \$10–\$5,000 range
Loan used for	Purchasing solar powered water pumps and small on- and off-grid solar installations	Full loan repayment	>90%
Clean energy produced	116 MWh	Cost saved	\$3500/year by switching to renewable energy
Operational cost reduction	34%	Capacity per installation	85.76 kw of clean energy

CERF Clean Energy Revolving Fund, *kw* kilowatt, *MWh* megawatt hour. *Sources* REEEP (2019), CERF (2019)

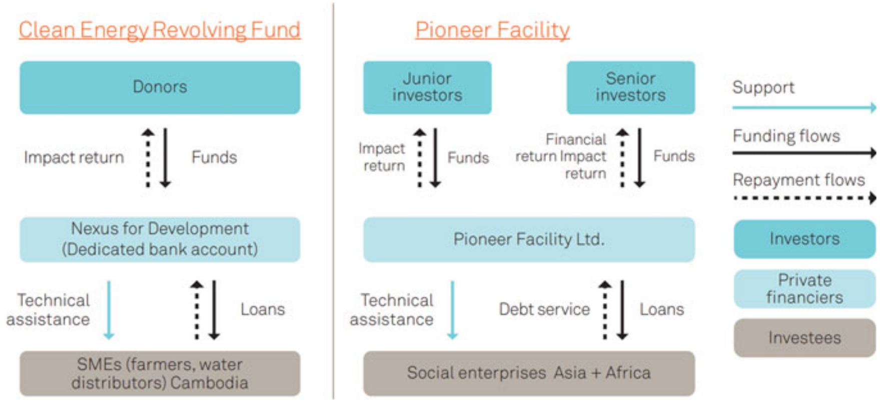

Fig. 5.8 CERF module and Pioneer facility. *SMEs* small and medium-sized enterprises. *Source* Nexus for Development (2019a, b)

5.4.5 Barriers to Improving Energy Efficiency

Although ASEAN member states have massive potential in investment opportunity, they are also lumbered with numerous challenges:

- The national objectives of environmental sustainability and coherent financial policy frameworks should work in tandem. The lack of incentives for capital and financial services providers prevents the financial system from being effectively aligned with broader sustainability objectives. Rather than focusing on the mandatory measures and incentives, the policies are predominantly focusing on voluntary activities, e.g., awareness and capacity building programs.
- The dominance of heavily subsidized fossil fuel industry and underdeveloped institutional mechanisms to implement the EE measures.
- Suboptimized energy standards throughout the region:
  - No fuel economy standards in the transport sector.
  - Low diffusion of energy efficient technologies in the industrial sector (except few countries and large industries) due to financing issues and lack of proper awareness.
  - In the building sector, most countries have energy codes, but their enforcement and stringency vary across countries (Fig. 5.9).
- Structural features of the ASEAN financial system create maturity mismatches, due to the dominance of relatively short-term bank financing. Investment pools that could substitute for bank lending are relatively shallow. This is in turn a function of high volumes of ASEAN household personal financial assets held in cash or deposits.
- Most of the companies have bureaucratic red tape—resulting in minimum environmental disclosure, and limited information-sharing platforms. This

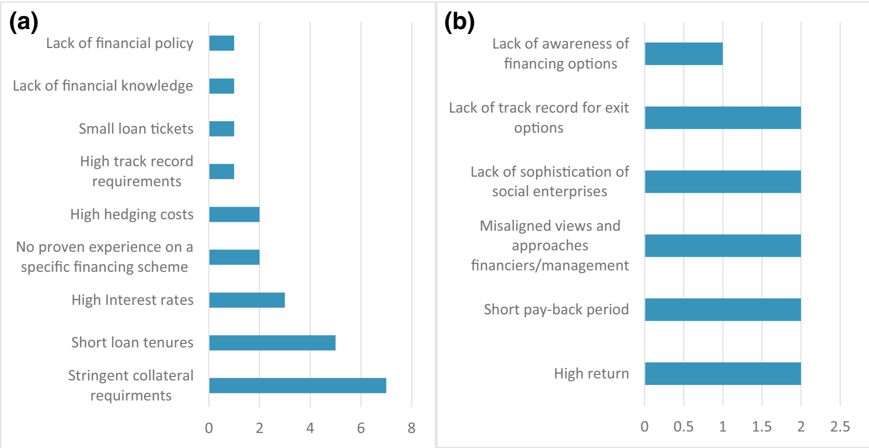

Fig. 5.9 **a** Top barriers to accessing debt financing for RE entrepreneurs, e.g., out of 10 entrepreneurs, 7 reported stringent collateral requirements as a barrier to access debt finance. **b** RE entrepreneurs' barriers to accessing equity financing. *Source* Data from the 10 entrepreneurs (2017)

breeds a difficult situation for the financial investors and policy makers to identify and manage the environmental risks. It also creates challenges in identifying new opportunities, and for companies trying to attract new sources of funding for securing energy efficiency.

5.5 Policy Recommendation and Conclusion

To promote energy efficiency and conservation (EE&C) implementation in ASEAN, financing is one of the most important factors to consider. This mapping study presents an overview of various financial support mechanisms available for EE&C across the ASEAN member states, identifies challenges, and provides respective recommendations to accelerate EE&C development in the region.

This chapter's findings show that EE&C institutional and policy framework at the ASEAN level is developed in which all ASEAN member states have adopted EE&C policies, programs, and roadmaps to achieve energy savings across different sectors. Key stakeholders were identified during the mapping of EE&C financing stakeholders in ASEAN. Government ministries, international development banks and/or agencies, national development banks, commercial banks, project developers including corporations, ESCOs, and utility companies all play an active role in EE&C financing in the region (Erdiwansyah et al. 2019).

EE projects with high rates of return remain unimplemented because of high investment risks, unavailable information on incentive schemes and mechanisms to project developers, lack of awareness on EE measures and insufficient skilled manpower. Other key challenges identified in this study include low energy prices and subsidies which disincentivize investments in EE&C projects and limited access to finance. In addition, lack of legislative measures to support the effective implementation of EE&C further hindering EE&C development in the region. To address some of the barriers in financing EE&C projects in the region, some ASEAN member states such as Singapore, Thailand, Malaysia, Indonesia, and Viet Nam have been able to develop more advanced frameworks by creating dedicated financing schemes for EE activities (e.g., Thailand provides grants, loans, equity, and guarantees dedicated to EE projects).

Based on our findings, the following critical recommendations should be followed to provide an uninterrupted EE financing plan in the region:

1. **Policy, Program, and Incentive Mapping:** Policy plays an important role in empowering energy efficiency. Both market and nonmarket-based policy instruments are required. APAEC articulates four strategies to achieve its energy efficiency targets. These include (i) harmonization of EE standards for energy-related products, (ii) enhancing private sector participation through ESCOs, (iii) development of green building codes, and (iv) increased participation of financial institutions in EE&C.
   However, there are still hurdles in implementation that governments are still trying to overcome. One such obstacle is inhibited access to funding. While governments have established grants to encourage the research and development in energy efficiency, these schemes are not sustainable due to limits on government funding. Governments have therefore attempted to encourage private means of financing for such forms of investment. This is impeded by the difficulty private institutions face in appropriately assessing risk, since the required technologies are nascent. Private institutions are therefore wary of investing in research and development in energy efficiency sources. This means that there is currently no sustainable, widespread funding mechanism for energy efficiency technologies. Governments therefore have to work more intimately with the private sector to increase knowledge about investments in this sector. Fortunately, they will be equipped with the increasing body of research and literature produced on the risk characteristics of energy efficiency investments that accompanies a global uptick in adoption of required technologies.
2. **Energy Efficiency in the Policy Mix:** It is necessary to examine the interaction of energy efficiency with targets in two related sectors: (i) increasing the uptake of renewable energy, and (ii) reducing GHG emissions in order to mitigate climate change.
   Since ASEAN does not undertake international climate negotiations as a bloc, the region does not have a singular climate policy or a defined GHG emissions reduction target. In this case, ASEAN's climate change mitigation goals are either encompassed by its collective EI reduction target, or by the energy efficiency and/or emissions reduction targets individually adopted by ASEAN member states through their nationally determined contributions.

Controlling energy consumption through energy efficiency measures is a cost-effective option compared with heavy investments in renewable energy infrastructure. Furthermore, as renewable energy technologies gradually become cheaper in medium to long-term, energy efficiency measures can address ASEAN's low-carbon energy transition in the short term. Therefore, to achieve this ASEAN renewable energy target, maximizing the region's energy efficiency potential is essential.

Some sector-specific recommendations are:

- Revise and/or remove fossil fuel subsidies and introduce market prices that reflect real economic costs.
- Conduct awareness raising for both policy makers and those in the implementation (e.g., commercial banks) and make available related information to all key stakeholders.
- Involve private players in the implementation, financing, reporting, and verification of EE&C projects. The private sector could introduce innovative financing instruments provided adequate regulatory frameworks are made available by the governments.
- Adapt most successful financing schemes in the region to the ASEAN member states' context. Relevant information to be provided and updated regularly through stakeholders' consultation.
- Develop relevant guidelines that include step by step processes for project developers and other stakeholders.

The ASEAN region had already achieved 18% reduction in energy intensity in 2015 and is well-placed to reach the target of 20% as stipulated in APAEC 2016–2020. Furthermore, to reach the long-term targets of 30% reduction in energy intensity by 2025, there is a need to innovate energy efficiency financing schemes and mechanisms and develop supporting policies. The implementation of financing mechanisms and schemes often face challenges as highlighted in this chapter. To overcome the ASEAN member states' specific and common challenges, an effective collaboration between governments, relevant stakeholders, and energy efficiency professionals can play a crucial role in developing policies and ensuring their effective implementation.

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Chapter 6
The Role of Fiscal Incentives and Market-Based Incentives in Promoting Energy Efficiency in the Industrial Sector: Case Studies from Asia

Tapan Sarker, Farhad Taghizadeh-Hesary, Aline Mortha, and Anjan Saha

Abstract In recent years, awareness about climate change and the need for cutting greenhouse gas has spread. Policymakers have hence chosen to promote the use of renewable energy, as well as encouraging improvements in energy efficiency (EE). This study analyzes the policy strategies of four Asian countries with large greenhouse gas emissions and EE strategies: the People's Republic of China, India, Indonesia, and Japan. The study first reviewed the type of instruments that can be used to reduce energy intensity, namely incentivizing policies (subsidies, tax reductions, and voluntary agreements) and market-based instruments (white certificates and tendering schemes). Through a review of the literature, the study identified advantages and weaknesses, as well as the effectiveness of said policies in the case studies. Fiscal incentives such as tax cuts and market-based instruments are shown to be efficiently reducing energy intensity. The study also highlighted the role of voluntary agreements and careful planning in successfully improving EE in the People's Republic of China. On the other hand, direct subsidies represented a heavy burden on the government's budget, with limited results.

Keywords Energy efficiency · Energy policy · Asia · Climate change

JEL Classification Q48 · Q54 · Q56

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6.1 Introduction

Many of the post-2015 United Nations (UN) Sustainable Development Goals are connected to the efficient use of energy in industries and households that have an enormous impact on material well-being, public health, climate change, and environment across the world. Energy is the dominant contributor to climate change, accounting for around 60% of the total global greenhouse gas emissions (UN 2018). By 2030, the UN expects double the global rate of improvement in energy efficiency (EE). The 2018 UN Environment Emissions Gap Report published in December 2018 highlighted fiscal policies as a key opportunity to reduce future emissions. In particular, a certain number of countries from Asia and the Pacific have committed to the use of efficient energy, through the Paris Agreement. Given that, this region includes many of the world's greatest greenhouse gas (GHGs) emitters, it is especially interesting to study their strategies and incentives implemented to increase EE, with a special focus on policies directed at the industrial sector.

Fiscal incentives play an important role in promoting investment in EE technology and are instrumental in the industrial sector development in Asia. Such incentives often provided via a country's tax system, offer tax subsidies, rebates, and tax holidays in investments in EE technologies. It also allows deductions and accelerated depreciation of capital expenditure in EE investments that include investment in research and development (R&D), and other related activities within the industrial sector.

To date, a number of Asian countries have adopted a range of fiscal incentives (FIs) in promoting investment in EE technologies. The FIs are aimed at industrial sector development using high-energy saving technologies and high-efficiency services. The intervention of FI policies is predominant both in developed countries such as Japan and in emerging economies such as the People's Republic of China (PRC), India, and Indonesia. Given the variation in policies and variation in the overall structure of the economies including their income, sociocultural, and awareness status, the results are mixed. This research aims at exploring the various EE schemes and incentives implemented in four Asian countries and directed at the industrial sector, which accounts for the majority of energy consumption. Given the mixed results of some policies, this study also aims at conducting comparative evaluation of the success of these initiatives, and eventually, providing policy recommendations for other countries. The novelty of this research lies in the analysis of Asian case studies, with a special focus on FIs and market-based Instruments (MBIs). This chapter paper is organized as follows. Section 6.2 provides a review of the literature on the topic. Section 6.3 introduces FIs, MBIs, and energy efficiency finance schemes implemented throughout the world, discussing their implementation, objectives, and results. Section 6.4 introduces the schemes in force in the selected four Asian countries. Section 6.5 concludes this study, and discusses various policy takeaways. Based on the case studies, this research highlights the positive impact of MBIs on EE, especially when combined with other instruments such as voluntary agreements and FIs.

6.2 Literature Review

EE is one of the keys to transform the future energy system (EC 2016). Empirical findings show that financial incentives increase EE investments (Datta and Filippini 2016; Datta and Gulati 2014; Markandya et al. 2009). Efficiency investments by industry and households and incentives for behavioral change will accelerate this transformation (EC 2011). Literature highlights financial incentives as key for successful EE outcomes, as financial funding motivates the growth and operation of energy-efficient products and technology, and incentives reduce initial investment costs and eliminate financial barriers to EE (Datta and Gulati 2014; Datta and Filippini 2016; Dubois and Allacker 2015; Galarraga et al. 2013; Galarraga et al. 2016; Grösche and Vance 2009; Hou et al. 2016; Markandya et al. 2009). The incentive of EE finance is larger in comparison with an equivalent increase in energy prices using taxes or tradable permits. Politicians are also keen to use this policy mechanism because of its popularity (Galarraga et al. 2016).

EE is related to energy pricing, the building of awareness, reduction of market barriers, and standardization of regulatory approaches. EE improvements lead to lower energy consumption and reduce the emission of greenhouse gases (UN 2019; IPCC 2019). The gap between the emissions target and actual emissions of each country is enormous. One of the reasons is that the amount consumers invest and the amount of expected investment in the interest of the consumers is large (Golove and Eto 1996). Governments, the International Energy Agency, and other international bodies are active in providing support to this end. Financial incentives play a major role in remedying the persistence of barriers to EE to change the market equilibrium towards an efficient equilibrium (de Miguel et al. 2015). Governments and international organizations, in partnership, have projects operating across the countries. Goulder (2013) explores the double dividend of fiscal incentives in EE finance. Fiscal incentives provide environmental improvement and a reduction in the costs of the tax system. Launched in 2010 by the Clean Energy Ministerial, the Super-Efficient Appliance and Equipment Deployment Initiative contributed to drastically improve EE of the household appliances and the other energy-consuming equipment.

For EE improvements, governments across the world are providing a range of incentives such as grants, loans, tax rebates, direct tax deductions, and exemptions. The incentives also include a reduction in sales tax on products eligible for efficient use of energy. For example, governments provide tax incentives to households in purchasing home appliances, equipment, and home shell items such as window insulation. The incentives are also provided to the equipment manufacturers and businesses selling the energy-efficient equipment.

While literature, in general, provides pronounced support for the use of FIs for EE improvements, it encourages a cautious approach, because of the rebound effect of FIs. A number of works note that energy-efficient improvements may lead to an overall increase in energy consumption, which may result in over-consumption of energy. The phenomenon is widely known as the rebound effect of financial incentives (Jevons 1865; Greening et al. 2000; Freire González 2011). The unpredictability and complexity of the use of various forms of FIs, the co-evolution of technologies and societies, the irreversibility of some of the phenomena, and political reasons may trigger the rebound effect. For instance, in Spain, the large-scale introduction of dishwashers in households through EE rebates reduced welfare in the economy (Galarraga et al. 2013).

Financial incentives may trigger over-consumption of some of the energy-efficient appliances and reduce welfare in the short term, however they remain an important instrument in spurring investment in EE initiatives. They are part of the long-term solution for achieving EE. The most intriguing part is that FIs can overcome market barriers and complement other policies (ACEEE 2019). As energy efficiency instruments may have a rebound effect, a number of works suggest a mix of instruments as an effective tool to mitigate over-consumption (bigEE 2019; Boonekamp 2006; Braathen 2007; Child et al. 2008; Rosenow et al. 2015, 2016). Rosenow et al. (2016), for example, highlight the importance of using energy tax in conjunction with fiscal incentives. They argue that energy tax provides a price effect that forces consumers to invest in energy-efficient technologies. The big EE projects argue that a combination of the performance standard and financial incentives reinforces EE, where the financial barrier is high. EE instruments may have both reinforcing and mitigating effects, as detailed in a study by Weise et al. (2018).

6.3 Review of Policies Improving Energy Efficiency

To analyze the policies implemented by Asian countries to improve energy efficiency, this section discusses the various instruments that are available for policy makers, including their advantages, drawbacks, and issues in implementation. This section is divided into two parts: direct incentives and market-based instruments.

6.3.1 Policies Incentivizing Energy Efficiency

The most straightforward instruments are direct incentives, such as subsidies, tax exemptions, agreements with firms or cooperation with firms directly through capacity building, and data collection of benchmarking.

Subsidies can take many forms. They can be direct subsidies, provided to industry or individuals by lowering the price of a certain technology. Differentiated pricing can be seen as a reward for good practices (Tanaka 2011). Subsidies can also take the form of extensive R&D programs to promote research in innovative EE solutions. While direct subsidies may be effective in increasing EE, they come at the cost of taxpayers, who are eventually, the ones financing the subsidies provided by the state. In addition, policy makers stumble on a critical question in implementing direct subsidies, namely, the proper price reduction that is to be provided by the state. As stated by Tanaka (2011), the amount must be high enough to encourage firms to switch to these new technologies, while keeping in mind that, the higher the amount, the more burden borne by taxpayers. When properly implemented, subsidies are efficient and do not require an extensive amount of data. However, the burden of the financing rests on the shoulders of taxpayers rather than polluters', and require a certain knowledge on "potential and corresponding costs of technical actions to be supported" (Tanaka 2011, p. 6547).

Fiscal policy, such as the imposition of taxes, tax rebates, and tax exemptions can also influence the development and promote the use of EE technology (Abdelaziz et al. 2011). Tax deductions for certain sectors for reducing the costs of energy investments can be found in Canada, Japan, the Netherlands, and the United Kingdom (Tanaka 2011). Praised by many economists, carbon pricing has been a popular policy instrument in many countries. However, many fear that carbon pricing endangers the industry's competitiveness, and for this purpose, tax exemptions can come alongside carbon pricing policies. For instance, in Sweden, manufacturing industries only pay 50% of the normal CO_2 tax rate. In Denmark the implementation of the carbon tax differentiated medium and high energy-intensive industries, applying a lowered rate for the latter (Tanaka 2011). Tax exemptions for high energy-intensive industries can raise many questions, especially when it comes to the efficiency of the tax. Taxation of the industry to promote EE, as well as cutting emissions and loss of competitiveness is a tradeoff that every policy maker needs to address before implementing the tax and its eventual exemptions. Similarly to pricing reductions, the exact amount of tax exemption requires a certain level of knowledge of the industry's cost structure. Besides, the issue of fairness and equity, as well as the efficiency needs to be addressed as well. With the exemptions of large emitters to safeguard their competitiveness, tax exemptions raise the question of why households and low and medium energy-intensive industries have to pay a higher share for their emissions.

While we have been discussing policy tools individually, clearly the majority of them come together with other instruments. This is especially the case for voluntary agreements. Following the implementation of a certain tax, regulation, or standard that may impede energy-intensive industries, voluntary agreements are proposed by governments, where volunteer firms agree upon a specific emissions reduction target and may receive a special discount from the tax, if the target is reached. Prime examples of voluntary agreements are Climate Change Levy Agreements (CCA) in the United Kingdom. While voluntary agreements tend to solve equity issues, their efficiency in reducing emissions and improving EE is questionable. Some studies found that results are mixed due to the lack of stringency of the targets (Cambridge Econometrics 2005), while others praised efficiency gains and emissions cuts thanks to the CCAs (Ekins and Etheridge 2006). Recent microeconometric evaluations of the climate change levy package provide more robust evidence of reductions in energy intensity and electricity use under the targets of the CCAs at the plant level (Martin et al. 2014). Indisputably, the success of voluntary agreements in improving EE lies in the stringency of targets negotiated directly with firms.

6.3.2 Market-Based Instruments

As Rosenow et al. (2019) imply, MBIs have been playing an increasing role in promoting EE around the world. They are now present in the European Union in the form of the Energy Efficiency Directive, set in 2012, as well as in various states in the United States, Australia, Brazil, the PRC, the Republic of Korea, and South Africa. Following Rosenow et al. (2019), we define MBIs as "instruments that set a policy framework specifying the outcome […] to be delivered by market actors, without prescribing the delivery mechanisms and the measures to be used." (Rosenow et al. 2019, p. 1380). One of the great strengths and efficiency of MBIs comes from the focus on outcome as opposed to the means of delivery, which leaves market agents more freedom to meet the obligations. However, MBIs do not come without shortcomings and may bring some challenges for policymakers, as they may lead to the concentration of a particular technology type. In addition, as instruments such as obligations are funded through energy prices, they may affect poorer households who tend to consume more energy as a proportion of their income (Rosenow et al. 2019).

The first type of MBI used for EE gains has many names: energy-efficiency obligations (EEOs), energy-saving obligations, energy-efficiency resource standards, energy efficiency performance standards (Rosenow et al. 2019) or white certificates (IPEEC 2016). It is a type of environmental commodity that "certif[ies] that a certain amount of energy savings has been achieved, when measured against a baseline or mandatory obligation, for instance, the energy efficiency obligation" (IPEEC 2016, p. 15). Under this scheme, and in compliance with the definition of MBIs stated above, white certificates or EEOs only define a given energy-saving target to be reached, leaving complete freedom to private sector agents to choose the means to attain it. Upon achieving a target, participants are awarded a white certificate, which can be traded between parties that are over-fulfilling their targets and those that are falling short on theirs (IPEEC 2016). In addition, white certificates can be traded between eligible parties and energy service companies (ESCOs) that do not have EEOs. Hence, EEOs are an accounting tool, used to keep track of energy saving achievements as well as a tradable commodity on the white certificates market (IPEEC 2016). The results of EEOs greatly vary between countries, which may be a result of differences in program designs, monitoring issues, and stringency of targets (Rosenow et al. 2019). For instance, a white certificate program was implemented in France from 2006 to 2009, with a target of 54 terawatts per hour of cumulative energy savings, and a penalty of €20 per megawatt hour for noncompliers, and was extended with more ambitious targets from 2011 to 2013 (IPEEC 2016). At the end of the program, about 84% of the target had been met, with lower costs than expected (IPEEC 2016). However, many unexpected challenges came along the implementation, namely the lack of sufficient competition in the market for white certificates, lack of knowledge about the scheme, and high costs of monitoring, and other administrative costs to allow for a high degree of flexibility (IPEEC 2016).

The second type of MBIs used to improve EE are auction mechanisms, which are called tendering schemes. They allow for market actors to "submit bids for the planning and implementation of energy efficiency projects" (IPEEC 2016, p. 6). The bid consists of the projected energy saving amount, as well as the budget required to achieve it: about 20% to 40% of the total costs (transaction, information, planning, design, investment, monitoring…) are comprised in the bid (IPEEC 2016), and the ratio between projected energy-saving and budget is the "price" of the offer (IPEEC 2016). Auctions can be funded through a great variety of streams, such as taxation (in the United Kingdom [UK]), a levy on energy bill (in Portugal), or on the transmission grid (Switzerland), or from emissions trading schemes (Germany), which allow for more flexibility than EEOs (Rosenow et al. 2019). However, unlike EEOs, they do not specify the overall saving target to be achieved, choosing the most appealing projects instead. Auction mechanisms are relatively new, and hence, hard to evaluate. The mechanism introduced by the UK in 2015 has been successful so far (IPEEC 2016), however, results tend to greatly differ depending on countries (Rosenow et al. 2019). IPEEC (2016) highlighted that one key element in the success of auctions lies in reducing the administrative burden to broaden participation, especially in the case of the UK.

This section detailed the various policy instruments that can be used to increase energy efficiency, which are summarized in Table 6.1. Direct incentives, such as subsidies, tax exemptions, and cooperative measures are relatively successful tools, however, they come with certain costs, which tend to be borne by the public sector, and hence taxpayers. MBIs, such as EEOs or tendering schemes can be efficient tools, but require careful implementation and unforeseen costs may arise.

Table 6.1 Summary of fiscal incentives and MBIs improving EE

	Type	Advantages	Weaknesses	Example(s)
Subsidies	Policy incentive	Efficient when well targeted	Costly Implementation issues (proper amount of subsidies) Lack of fairness as taxpayers bear the burden of the subsidies	Indonesia
Tax exemptions and rebates	Policy incentive	Efficient when well implemented	Implementation issues (proper pricing and amount of rebate) Lack of fairness as taxpayers bear the burden of the subsidies	Sweden, Denmark
Energy efficiency obligations	Market-based Incentive	Cost-efficient Improvements in EE Well-defined target	Unexpected costs may arise Need for proper monitoring	White certificates in France
Tendering schemes	Market-based incentive	Cost-efficient Improvements in EE Lower administrative burden	No overall saving target specified	Switzerland, Germany, Portugal, United Kingdom

EE energy efficiency, *MBI* market-based instrument. *Source* Authors' compilation

6.4 Energy Efficiency in Selected Asian Countries

The Asia and the Pacific region is one of the major emitters of CO_2. To reduce their carbon footprint and meet their Sustainable Development Goals targets, many countries in the region have opted for policies increasing energy efficiency. In this section, we detail the strategies, challenges, and effects of energy efficiency policies employed by four prominent Asian economies: the PRC, India, Indonesia, and Japan. Table 6.2 summarizes the key features of these economies.

From these figures, it is clear the four chosen economies are different in terms of development and maturity: Japan shows a high level of GDP per capita and low GDP growth rates while emerging countries such as India, Indonesia, and the PRC present high growth rates with relatively lower GDP per capita. It is important to keep in mind that developed and emerging countries also have different levels of maturity of their financial system, and hence, tend to use different types of instruments. Regardless of their level of development, these four economies also have different levels of endowments in natural resources. For instance, India and Indonesia are relatively well endowed and rely more on their renewable resources compared to the other three. Figure 6.1 shows the evolution of the energy intensity of GDP in the four countries, which will be more thoroughly discussed below.

6.4.1 People's Republic of China

The magnitude of the PRC's energy consumption, outstanding growth rate, role in the region, and significance to global climate mitigation makes the country essential in our analysis. In addition, the PRC government announced in 2005 its intention of reducing energy consumption per unit of GDP by 20% between 2005 and 2010

Table 6.2 Comparison of four Asian economies in 2014

Indicator	PRC	India	Indonesia	Japan
Size of economy (GDP in current trillion $)	10.44	2.04	0.89	4.85
GDP per capita (current $)	7,651.37	1,573.88	3,491.63	38,109.41
Economic growth (%)	7.30	7.41	5.01	0.38
Energy use (thousands kg of oil equivalent per capita)	2,236.73	636.57	883.92	3,470.46
Fossil fuel energy consumption (% of total)	87.67	73.58	66.09	94.41
Energy intensity level of primary energy (2011 PPP GDP)	7.10	4.96	3.68	3.87
Renewable energy consumption (% of total energy consumed)	12.22	36.65	37.45	5.63

GDP gross domestic product, *PPP* purchasing power parity, *PRC* People's Republic of China. *Source* World Bank database rounded to two decimals

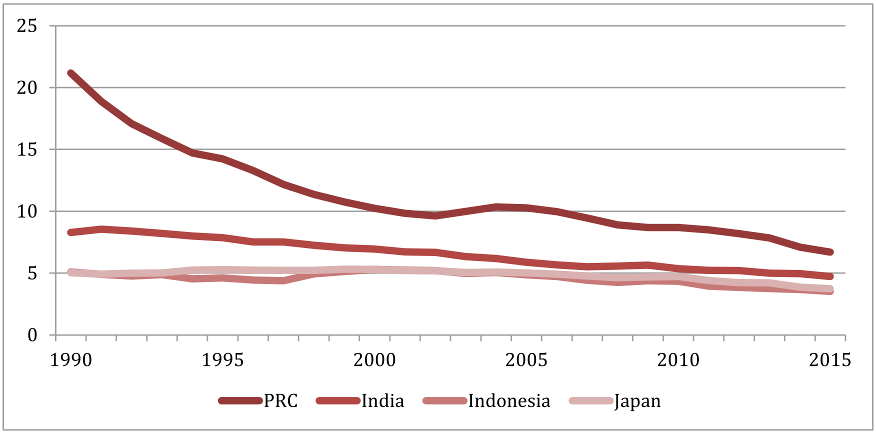

Fig. 6.1 Evolution of energy intensity of GDP in four Asian countries. *PRC* People's Republic of China. *Source* World Bank database

(Price et al. 2010). As illustrated by Fig. 6.1, the evolution of the country's energy intensity has been falling dramatically over the years, thanks to numerous schemes and policies to increase energy efficiency.

Many policies and subsidies schemes have been put in place, in addition to increasingly severe regulations and standards. For instance, the country provides "subsidies as a small portion of […] energy efficiency investment and rewards according to the amount of energy saved" (Zhu and Chertow 2017, p. 12). Since 2016, a fund to support projects in smart manufacturing, consumer goods, and green manufacturing has been put in place, under the supervision of the Ministry of Finance and the Ministry of Industry and Information Technology (IEA 2019), and grants loans, credit guarantees, insurance, and subsidies to relevant projects. Decentralization is also key, as financial support is granted to provincial energy conservation centers (Xinjiang, Ningxia, Qinghai, Gansu, Yunnan, Guizhou, Sichuan, Shanxi, Guangxi, Liaoning, Heilongjiang, Jilin, Hubei, Henan, Shannxi, Hunan, Anhui, Chongqing) both by central and local governments (Price et al. 2010).

Tax rebates for exports of energy-intensive products have also been used. In 2006, the PRC's Ministry of Finance reduced export tax rebates for low value-added but high energy-consuming goods. The rebate varied depending on the product: 11% to 8% for steel, from 13 to 8% for cement, from 13 to 11% for glass, and from 13 to 5%, 8% or 11% for some nonferrous metal products (Price et al. 2010). A different electricity pricing policy has also been applied since 2004. Industries are placed in four categories of energy efficiency—encouraged, permitted, restricted, and eliminated—and are charged higher electricity rates to discourage and "phase out inefficient enterprises" (Price et al. 2010). Between 2004 and 2006, approximately 900 firms and 380 firms in the eliminated and restricted categories respectively, have closed, invested in EE, or changed their production processes (Price et al. 2010).

Apart from fiscal incentives, the PRC also introduced MBIs. In 2010, the PRC also introduced energy efficiency obligations to attain 14,578 gigawatt hours of energy saving per year (IEA 2019). Obligated grid companies were forced to reach a savings of 0.3% of electricity sales compared to the previous year. ESCOs were also targeted through energy-saving performance contracts (EPSCs), and provided financing and initial management in EE projects, gathering information and data with the contracted firm. EPSCs had a great impact on mitigating concerns over high upfront costs and helped share expertise in EE (Zhu and Chertow 2017). Since 2011, the National Development and Reform Commission (NDRC) also started a pilot program of emissions trading in Beijing and six other provinces, and the first carbon emissions quota trading market was launched in Shenzhen 2 years later. At the end of 2014, the seven pilot regions had a cumulative trading quota of 30.53 million tons of CO_2, with a turnover of CNY814 million (International Energy Charter 2018).

The country also multiplied the use of other types of instruments, such as voluntary agreements and EE finance. Since 2006, the PRC has implemented the Top 1000 Industrial Energy Conservation Program, a voluntary agreement between the government and large-scale enterprises in nine energy-intensive fields (iron and steel, petroleum and petrochemicals, chemicals, electric power generation, non-ferrous metal, coal mining, construction materials, textiles, and pulp and paper) that each consumed a minimum of 180,000 tons of coal equivalent in 2004 (Price et al. 2010). The agreement set targets of energy efficiency for these top 1000 enterprises to achieve approximately 100 million tons of coal equivalent savings. Evaluation of the program fell under the purview of provincial governments. This program is reported to have saved 20 metric tons of carbon equivalent (Mtce) in 2006 and 38 Mtce in 2007, for a total of 58 Mtce savings (Price et al. 2010). Energy agreement also contributed to the implementation of an energy audit, identifying energy-saving potential. It also encouraged informal information sharing about advanced technologies and national policies in place between public and private actors (Zhu and Chertow 2017). This particular example shows that, in addition to fiscal incentives, voluntary agreements can help achieve large EE gains. Furthermore, the China Energy Efficiency Financing Program (CHEEF) was established by the World Bank, which provided $100 million each to two participating local financial institutions: Exim Bank and Huaxia Bank (IEA 2011). After including Minsheng Bank in a second phase, the program has now been expanded to a third phase with additional financing for ESCOs, the building sector, and an increased leverage ratio. The risk-sharing scheme in the form of the International Finance Corporation (IFC) and the Global Environment Facility (GEF) China Utility Energy Efficiency (CHUEE) Program also started in 2006 and supported marketing, project development, and equipment financing, bringing together financial institutions, utility companies, and suppliers of EE equipment. The IFC/GEF insured 75% of the first loss, and 40% of second losses, leaving the remaining burden to commercial banks (IEA 2011). The program is estimated to reduce emissions by 14 million tons per year, providing $197 million worth of guarantee (IEA 2011).

6.4.2 India

Compared to the other countries in the study, India has a long history of energy efficiency policies. The Companies Act encouraged industries to disclose energy efficiency, energy consumption, value-added amount of their major products as early as 1988 (Abdelaziz et al. 2011). In 1991, the liberalization of the regulatory regime helped increasing industrial competitiveness, and since this date, energy intensity has been steadily decreasing, as illustrated by Fig. 6.1 1995 marked the year where the government officially adopted a policy to improve energy efficiency by "allowing the accelerated depreciation for energy efficiency and pollution control equipment" (Yang 2006, p. 3108), and in 1997, the public invested $12 billion in the forms of subsidies for industrial energy efficiency.

A turning point of India's EE policy came with the enforcement of the Energy Conservation Act of 2001, allowing energy-intensive 5 years to comply with mandatory provisions, such as norms for energy consumption, mandatory energy audits, efficiency standards and labeling, and mandatory appointment of energy managers (Abdelaziz et al. 2011; Yang 2006). While this act is an example of command and control policy rather than an incentive, it remains a turning point in Indian policy and contributed to improving EE.

In more recent years, a special emphasis has been put on easing access to finance for EE projects through special credit lines and risk-sharing systems for small and medium-sized enterprises (SMEs). The Kreditanstalt fur Wiederaufbau Bankengruppe (KfW) of Germany has created a special credit line and dedicated €50 million to the "Small Industries Development Bank of India (SIDBI) to finance EE projects in micro, small and medium enterprises (MSMEs) in India" for projects that achieve a minimum level of energy savings and GHG emissions reduction (IEA 2011, p. 18). The KfW is also in charge of providing technical assistance to SIDBI to identify targets, setting up credit lines, and conducting awareness campaigns in MSMEs throughout India (IEA 2011). The objective of this program is to reduce 25 tons of GHG emissions for every ₹1 million invested (IEA 2011). Also, two risk guarantee funds are implemented in recent years. Since 2016, the Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) provides a 50% guarantee of loan amounts for EE projects from government buildings and private buildings. So far, the five financial institutions taking part in the project are: Andhra Bank, Yes Bank, Tata Cleantech Capital Ltd., IDFC Bank, and IndusInd Bank (IEA 2019). The Venture Capital Fund for Energy Efficiency (VCFEE) established in 2017, invests in EE projects in the form of equity. The fund provides last-mile equity, limited to 15% of total equity or ₹20 million (IEA 2019).

Nevertheless, subsidies programs are still implemented in the country. The National Energy Conservation Award rewards industries that have significantly reduced energy consumption and increased EE since 1991 (IEA 2019). Implemented in 2015, the Facility for Low Carbon Technology Deployment (FLCTD) is a joint grant program, supervised by the Bureau of Energy Efficiency, the United Nations Industrial Development Organization, and supported by the Global Environment Facility (GEF). The FLCTD conducts an annual competition to identify the best low carbon technologies and solutions to improve EE, and winners are awarded special grants from GEF and FLCTD (IEA 2019). The GEF also funds the Creating and Sustaining Markets for Energy Efficiency, implemented by the Asian Development Bank and Energy Efficiency Services Limited since 2017. This project is aimed at expanding the market for LED and street lighting, and providing competitive grants to pilot projects (IEA 2019).

Finally, India has created a program of energy saving certificates, called the Perform, Achieve, Trade (PAT) since 2011. The first cycle of the PAT scheme targeted 400 energy-intensive firms, known as the designated consumers, and reduced their consumption by 9.4%, far above the initial target. The trading of the savings certificates is key to the success of the PAT program and served as an incentive to reach and even surpass the mandatory targets. Each certificate is equivalent to 1 ton of oil equivalent of energy savings, are given based on quantified energy savings verified by an energy auditor, and are then traded on the energy-saving certificate market, regulated by the Central Electricity Regulatory Commission (IEA 2019).

6.4.3 Indonesia

Indonesia is eager to use energy subsidies to promote the development of energy efficiency among other things, despite it being extremely onerous on the government's budget. In 2012, the Indonesian government allocated Rp137 trillion to fuel subsidies and Rp65 trillion for electricity subsidies, leaving only 20% of the budget for food subsidies, fertilizer subsidies, seed subsidies, credit subsidy programs, and tax subsidies (Setyawan 2014). To save part of this budget, Indonesia's Ministry of Finance has been attempting to provide fiscal incentives to encourage energy savings in the form of providing tax incentives and different facilities on components/spare parts and raw materials for energy-efficient appliances (Setyawan 2014). Despite such efforts, these incentives did not result in EE gains (Setyawan 2014). As shown in Fig. 6.1, Indonesia's energy intensity has been relatively stable over the years, with a slightly decreasing trend.

Besides, Indonesia has been doing some efforts in raising awareness. Since 2016, the Kampanye Potong 10% (10% Cut of Energy Use Campaign) targets stakeholders in the energy sector (government institutions, industry, nongovernment organizations, general public, etc.) to encourage them to reduce their energy consumption by 10% (IEA 2019). Also, the Konservasi Energi Goes to Campus

(Energy Conservation Goes to Campuses) is an awareness-raising program directed at university students and introduces them to the basic principles of energy efficiency, and presents job opportunities in the sector (IEA 2019). In general, many cooperative schemes are implemented in the country, from capacity building programs to technical assistance (Indonesian financial support [INFIS], green building program, ESCO program, and first movers program until 2017) (APEC 2017).

Much has been attempted in the country to provide financial assistance: concessional credit lines such as loans to EXIM Bank jointly with the Asian Development Bank, EE concessional loans (provided by the Ministry of Energy and Mineral Resources and Agence Française de Développement), the EE revolving fund, and Industrial Efficiency and Pollution Control (IEPC) (supported by KfW and Ministry of Energy and Mineral Resources have been stopped due to the lack of fund availability and limited results (APEC 2017). Nevertheless, the Joint Credit Mechanism, together with the Japanese government, still acts as a fund for technology subsidies. The Clean Technology Fund (CTF) also promotes EE initiatives since 2012, with a budget of $400 million. The plan mostly aims at expanding geothermal power plants and increase EE through risk-sharing facilities for small and medium investments (IEA 2019).

6.4.4 Japan

After the two consecutive oil shocks of the 1970s, Japan was severely affected and undertook several policies to promote energy security through the promotion of renewable energy (Sunshine Project) and the promotion of energy conservation technologies (Moonlight Project) as early as 1978 (IEEJ 2016). In addition to R&D subsidies, Japan has been providing special loans for enterprises for efficient energy use since the mid-1970s, in addition to special tax depreciation for energy-saving facilities, which still exist nowadays in the form of the green investment tax cut (IEEJ 2016). The tax consists of a price reduction of 30% on targeted equipment, or 7% of tax reduction for SMEs (IEA 2019). Also, SMEs have benefited from preferential financial measures (loan, tax, subsidies) since 2010. For instance, special interest rates are applied for energy efficiency facilities and for installing EE equipment. Special interest rate loans are also granted for EE projects by the Japan Finance Corporation (IEA, 2019). Finally, the government allocated ¥41 billion in subsidies (IEA 2019).

Following the Kyoto Protocol, the Keidanren (Japan Business Federation) voluntarily presented the Keidanren Voluntary Action Plan on the Environment (Keidanren 1997). Thirty six industries in various sectors (manufacturing, energy, distribution, transportation, construction, foreign trade, nonlife insurance, etc.), represented by 137 organizations pledged to combat global warming by setting targets of energy reduction and emissions reduction on their own (Keidanren 1997). Concrete measures undertaken by industries include “the formulating of careful and detailed innovations relating to operations control, including energy conservation in offices; making improvements in equipment and processes; and engaging in and implementing the developments from technological research." Industries also engage themselves in annual reviews on the efficiency of the plan. If initially only 36 industries were included, 114 industries in commercial, manufacturing, transportation, and energy conversion sectors took part in the plan in 2012 (METI 2014). Since 1997, the Ministry of Economy, Trade and Industry estimated that "Japan had improved efficiency levels by approximately 33% as a result of energy-saving efforts since the oil crises" (METI 2014, p. 7).

Japan introduced the J-Credit Scheme in 2008, a program that promotes GHG emissions reduction through energy-saving and forestry management. The reduction in GHG emissions is approved by the state and recognized as a "credit". Credit issuers can be SMEs, farmers, owners of the land, or local governments, which, through the installation of energy-efficient equipment, investment in renewable energy or proper forestry management, achieved GHG emissions cut. They can sell their credits to large corporations, other SMEs, or local governments, which are encouraged to buy J-credits for good public relations and corporate social responsibility, as well as receiving praise from ministry officials (Japan Credit 2019). Finally, Japan provides cooperative schemes in the form of audits for SMEs, as well as information sharing. Since 1997, the country provides free energy audits for SMEs, conducting about 10,000 between 2004 and 2014 (IEA 2019). Besides, the Energy Conservation Centre Japan has been publishing technical guidebooks and implementation guidelines for energy management in factories since 2001 (IEA 2019).

6.5 Conclusion and Policy Recommendations

With rising awareness about climate change, many countries in Asia pledged to reduce their GHG emissions, through international channels such as the Kyoto Protocol, the Paris Agreement, or the UN Sustainable Development Goals, or simply through targets set at the national level. As the Asia and Pacific region remains the largest contributor to GHG emissions, this region also includes many countries that implemented many strategies to reduce their emissions, whether by promoting renewable energy or by stimulating EE. This study attempts to analyze the policies incentivizing EE from four Asian countries: the PRC, India, Indonesia, and Japan.

The study first reviewed various instruments that can be used to increase EE. Incentivizing policies, such as subsidies and tax exemptions can be very efficient if well-targeted, however, remain costly and the burden of emission reductions is borne by taxpayers rather than polluters. Voluntary agreements, on the other hand, can be efficient tools but need careful planning, monitoring, and their outcome heavily depend on the stringency of the targets negotiated between the governments and the private sector. As other types of incentive, emissions trading schemes and cooperative policies may also be used, although their outcome is more uncertain and may not necessarily result in EE gains in the short term. MBIs such as EEOs or tendering schemes are also cost-efficient instruments that can reduce energy intensity. Nevertheless, monitoring remains a problem during implementation. Finally, special credit lines or risk-sharing scheme, are both programs that can encourage EE projects by unlocking funding that may normally not be available due to the belief that EE projects are riskier.

The study then moved to the analysis of the EE strategies of four Asian countries. While India and the PRC, in particular, have experienced a spectacular decrease in energy intensity, Indonesia and Japan have been stable. Table 6.3 summarizes the various instruments and policies promoting EE in the four countries.

From Table 6.3, it is clear that part of the PRC's success is attributed to the multiplication of instruments and its overall planning strategy. Both the PRC and India have successfully implemented MBIs in the form of EEOs or white certificates, which could also explain their recent EE improvements. Besides, the literature praised the effectiveness of voluntary agreements such as the Top 1000 Industrial Energy Conservation Program in the PRC (Price et al. 2010) or the Keidanren Voluntary Action Plan on the Environment in Japan (METI 2014). On the other hand, extensive subsidies are burdens and barely contributed to EE improvements in the case of Indonesia (Setyawan 2014). While all countries in the case studies have subsidies for EE, they remain marginal and are not at the core of the EE strategy, except in the case of Indonesia. Finally, it is complicated to assess the effectiveness of the case of cooperative schemes or EE finance, although they remain crucial for spreading awareness about EE in the long term. Nevertheless, EE finance programs are often terminated due to a lack of funding (APEC 2017). Spreading awareness about EE plays a decisive role in improving EE, and, despite its lack of accountability, should not be overlooked.

The review conducted in this study provides several important policy recommendations. The extreme reliance on subsidies proved to have little effect on EE, as shown by the case study of Indonesia. Of the remaining countries in the case study, those that relied on subsidies to promote energy efficiency used them as a marginal measure. The study also highlighted the effectiveness of MBIs, as exemplified by the spectacular EE improvements in the PRC and India. The review also showed the effectiveness of policies that act as complement of fiscal incentives, such as voluntary agreements, as shown by the success of the Japanese Keidanren and the PRC's top 1000 program. In fact, the example of the PRC reveals that the multiplication of EE policy instruments and carefully crafted planning strategy can lead to drastic EE improvements. In general, case studies proved that energy efficiency policies cannot be successful on their own, and produce better results when used complementarily. Nonetheless, it remains difficult to generalize the effectiveness of EE policies, as their success depends on the country of application, and on the level of financial development in said country. For instance, MBIs and tax incentives are more easily applicable in economies with mature financial systems. If not properly implemented, these types of policies may have a harmful effects on the economy. Simulation of policy implementation, and quantitative policy evaluation are left for further studies on the topic.

Table 6.3 Summary of incentives promoting energy efficiency in four Asian countries

	PRC	India	Indonesia	Japan
Subsidies	Subsidies since 2005 Special fund since 2016	Subsidies since the 1990s	Subsidies since 1997	Subsidies since 1978
Tax and tax exemptions	Tax rebates for exports of energy-intensive products Different carbon pricing policies, sanctioning energy-intensive industries		For commercial buildings	Mainly directed at SMEs
Voluntary agreements	Top 1000 Industrial Energy Conservation Program			Keidanren Voluntary Action Plan on the Environment
Emissions trading schemes	Pilot program since 2011 in seven provinces			Tokyo and Saitama prefectures only since 2010
Cooperative schemes	Energy audit and information sharing since 2006	Mandatory audits since 2001	Information sharing, technical assistance, capacity building	Free energy audit for SMEs and information sharing
White certificates tendering schemes	EEOs since 2010	PAT scheme since 2011		
Special credit lines	China Energy Efficiency Financing Program	KfW	Joint Credit Mechanism	Mainly directed at SMEs
Risk-sharing schemes	IFC/GEF China Utility Energy Efficiency since 2006	PRGFEE since 2016 VCFEE since 2017	Clean Technology Fund	
Others	Energy saving performance contracts Top runner program (regulation and standards)	Strong regulations and standards		J-Credit Scheme since 2008 Top runner program (regulation and standards)

EEO energy efficiency obligation, *GEF* Global Environment Facility, IFC International Finance Corporation, *PAT* Perform Active, Trade, *PRC* People's Republic of China, *PRGFEE* Partial Risk Guarantee Fund for Energy Efficiency, *SMEs* small and medium-sized enterprises, *VCFEE* Venture Capital Fund for Energy Efficiency. *Source* Authors' compilation

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Chapter 7
Promoting Energy Efficiency Through Foreign Direct Investments: Evidence from South Asian Countries

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Abstract This study investigates the impact of foreign direct investment on industrial energy intensity by incorporating economic growth, energy prices, industrial value-added, and carbon emissions in the South Asian countries for the period 1990–2018. We employ panel fully modified ordinary least square and dynamic ordinary least square. Our empirical results find that a stable foreign direct investment (FDI) and industrial energy intensity nexus exists and a 1% increase in FDI reduces total industrial energy intensity by 0.02%. Furthermore, this study applies the vector error correction model Granger causality test, results show that there is a bidirectional causal relationship between industrial energy intensity and FDI, and an unidirectional Granger causality running from industrial value-added and carbon emissions to industrial energy consumption in the long-run. In the short-run, the findings show the two-way causality between industrial energy intensity and foreign direct investment. Furthermore, a causal association from economic growth to FDI and carbon emissions. Based on empirical evidence, this study suggest that energy efficiency policies should be implemented for a sustainable development, environmental benefits, improving energy intensity will lead to long-term growth gains.

Keywords Industrial energy intensity · Foreign direct investment · Energy prices · DOLS · FMOLS · South Asia

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7.1 Introduction

Energy serves as an important stimulus for the rapid growth of any economy. Extensive consumption of energy can help countries achieve economic development as industrialization and urbanization contribute to rising incomes. The South Asian countries over the last 4 decades have received a substantial amount of foreign direct investment (FDI) in the energy sector with consistent economic reform policy measures emphasized on integrating the economy to the rest of the world (Jha et al. 2013). Countries such as Bangladesh, India, Pakistan, and Sri Lanka are focusing on energy investments to meet the rapidly increasing energy demand. By taking the right advantage of FDI, developing countries can develop long-term partnerships and have access to the new technologies that create energy efficiencies to self-sustain their economy (IMF 2008). Improving energy efficiency is not only important from an environmental protection perspective but also is vital for South Asian economies to meeting the micro-level energy needs of local communities that can drive sustainable economic growth.

A crucial role of governments in South Asia is to implement economic policies that promote positive externalities through green financing which is an investment made in sectors such as renewable energy. This can boost the economy by enhancing supply and demand for goods, services like electrical vehicles, and subsidies which will generate external benefits and welfare gain to the society. Renewable energy sources prove to be one of the most efficient and effective solutions for sustainable energy in developing economies globally. This chapter addresses policy issues and options to meet increasing energy demand by emphasizing FDI particularly for renewable sustainable energy investment in South Asian countries. Development and expansion of alternative energy would also help contribute to maintaining the environmental balance, employment generation, and inclusive development.

In 2014 alone, $90 billion was spent in energy efficiency projects around the world, reaching $231 billion in 2016. Although European countries spent the most on energy efficiency, major growth was seen in the People's Republic of China (PRC) where the energy efficiency policies have been strengthened along with structural changes to reduce the energy intensity of the economy (IEA 2016). Energy efficiencies are achieved through controlled air-conditioning installations, energy-saving light bulbs, and building pipe insulations. Similarly, providing low-interest loans by commercial banks for investments in renewable energy and government reduction in tax could be some measures from stakeholders in strengthening energy efficiency.

FDI is regarded as a source of financing which creates stability and provides competitiveness to various industries of a country to achieve sustainable economic growth and innovation, thereby expecting to promote energy efficiency as well.

Foreign direct investment also brings spillover effects in the host countries which can be both positive and negative. On one hand, it introduces advanced technology to improve energy efficiency and the improvements in energy efficiency may further lead to a "rebound effect", as more efficiency leads to rapid growth in the economy. This will, in turn, lead to growing energy consumption (Jevons 1866). On the other hand, the host country's environmental regulation could be weakened leading to various energy and environmental-related hazards coming due to a negative spillover effect of FDI.

The financial market has a crucial role in creating stability and providing competitiveness to various industries of the country to achieve sustainable economic growth. External financing is crucial in creating energy efficiency investments. The financial role of various multilateral organizations provides supporting evidence in countries where sustainable energy finance programs provided them with an opportunity to create both economic and ecological benefits. Similarly, multiple stakeholders including those who finance, facilitate, produce, and consume energy have discussed and raised the issues of the energy sector, government policy, and promotion of FDI to enhance the renewable energy market. Energy efficiency and decarbonized energy supply are the major drivers of the global reduction in emissions of key local air pollutants between now and 2040, according to the energy efficiency market report by (IEA 2016).

Previous literature contained a small number of empirical studies with mixed findings on the FDI–energy consumption nexus. For instance, earlier studies by Mielnik and Goldemberg (2002) and Doytch and Naryan (2016) find a negative relationship between FDI and energy use for a number of countries, while Salim et al. (2017) also find a negative association between FDI and energy in the PRC. However, Sadorsky (2010) and Lee (2013) conclude that FDI raises energy consumption in the host countries.

Therefore, given the inconclusive findings, this study is essential for the empirical investigation in the interlinkages between FDI and industrial energy use in the resource-rich South Asian countries between 1990 to 2018, where fully modified least squares (FMOLS) and dynamic ordinary least squares (DOLS) model have been applied. In general, the empirical results show a negative association between FDI and the nonrenewable nexus. The overall finding suggests that although FDI reduces industrial energy use, the result is negative but insignificant for renewable industrial energy use. This implies that the South Asian countries should invest and expand hydro-electric generation, which is also an important source of sustainable energy.

The remainder of the chapter is structured as follows. Section 7.2 reflects and examines various evidence associated with the energy consumption growth linkages with foreign direct investment and energy efficiency based on the existing literature for the countries and regions around the world. Section 7.3 demonstrates the details of the dataset and methodology followed by Sect. 7.4 which presents a discussion of empirical findings. Section 7.5 concludes the chapter and offers policy recommendations.

7.2 Literature Review

Improving energy efficiency for sustainable economic growth has been heavily emphasized by governments all around the world including the South Asian countries. Investment in renewable energy is of growing importance to FDI as this sector has been largely incentivized along with increasing consumer awareness toward environment-friendly products. However, the literature studying the impacts of FDI on industrial energy consumption is limited.

Zhao et al. (2019) explored the case of the PRC to depict how FDI can reduce regional energy efficiency differences by investigating the existence of energy intensity convergence while incorporating foreign direct investment. Panel data were used from 30 provinces in the PRC over the period of 2005 to 2014 to test energy intensity convergence with the help of the beta convergence model. The findings showed that FDI can strengthen the formation of convergence of conditional energy intensity, given the data's spatial dependence. The spillover impact of FDI, which is also global, inhibits a declining speed of energy intensity during the time of study. Hence, the result showed how having foreign investment in a reasonable way in the provinces of the PRC can contribute toward achieving energy efficiency.

Various best practices on energy efficiency have been identified by Retallack et al. (2018) based on an evaluation of 10 case studies, interviews, and past initiatives. The paper focused on the role of strong policy frameworks to strengthen investment with the right economic and regulatory drivers. Market mechanism activities are emphasized such as pipeline generation, upskilling, equipment to ensuring stakeholders such as suppliers and technical advisors abide by sustainability standards in the value chain. The creation of sustainable private sector markets by implementing smart public programs is likely to overcome the energy efficiency challenges and reduce energy demand.

Econometric techniques based on the total factor productivity and efficiency analyses have played a crucial role in analyzing the renewable energy efficiency levels in existing studies. Gökgöz and Güvercin (2018) showed that the average energy efficiency has been increasing using data envelopment analysis for certain EU countries. In Latvia, the short, medium, and long-term impact of different national consumer-oriented policies on energy efficiency in the residential building sector was analyzed by using a system dynamics approach. Blumberga et al. (2018) found that grant schemes are beneficial for energy performance measures but not enough for the fast implementation of large-scale energy efficiency improvements in the European Union.

Doytch and Narayan (2016) examined the impact of FDI flows on renewable and nonrenewable industrial energy sources for 74 countries to find that there is a reducing effect of energy consumption concerning nonrenewable sources of energy and an augmenting effect of energy consumption for renewable energy. Moreover, Sadorsky (2010) uses generalized method of moments estimation techniques to check the impact of financial development on energy consumption in a sample of emerging countries to find a significant relationship between FDI and energy use.

The United Nations' Sustainable Development Goals have been used as a benchmark for identifying the synergy effects provided by renewable energy with an analysis of possible leverage points for inclusive and sustainable growth (Schwerhoff and Sy 2017). The available instruments and actors involved show that there remains a large additional potentiality as to how renewable energy can provide sustainable economic development.

Jha et al. (2013) analyzed the determinants of FDI in South Asia from 1990 to 2010 and concluded that trade openness, gross domestic product (GDP), and direct investment have a significant positive impact on FDI, although labor has a negative impact. Economic growth and foreign direct investment are often complementary hence, the increase in a country's GDP implies that the FDI is strengthened and vice versa. The findings by Doytch and Narayan (2016) supported the idea that providing FDI technology to host countries would reduce the use of non-clean energy and promote the use of renewable energy, which is considered to be a driving force to improving energy efficiency.

When foreign companies enter a host country, they bring various management experiences, technology for production, and innovative ideas of low-carbon economy, energy-saving, or reduction in emission. Foreign companies also involved in advocating the host country to invest more in managing environmental pollution as well as reducing energy waste by enhancing the national sustainable development capacity (Perkins and Neumayer 2008). In the case of the PRC's economic development, Cheng and Kwan (2000) noted that FDI combines capital, technology, marketing, and management by not only making up for the lack of fund in the process, but also bringing new management experience and advanced technology for future growth. Globalization indeed plays an important role in fast-spreading of renewable solar energy generation as rightly pointed out by Meneguzzon et al. (2015).

Meanwhile, there are also several studies that show the negative impacts of FDI. According to Copeland and Taylor (2004) several countries seem to be reducing the degree of environmental regulation given the growing trend of economic liberalization, in order to improve their competitive advantage. Kolstad and Wiig (2012) found that there is rapid acceleration in the use of natural resources in the host country and large amounts of energy are consumed creating pollution-intensive products although FDI brings in capital and technology. Behera and Dash (2017) found that primary energy consumption and FDI have been substantially increasing the CO_2 emissions and accelerating the regional environmental degradation too based on a panel data of 17 countries in the South Asian and Southeast Asian economies. Another perspective in the improvements in energy efficiency induced by advanced technology brought in by FDI is the promotion of rebound effects as many empirical studies show. According to Sorrell et al. 2009) the increase in energy efficiency reduces the price of energy services and stimulated the increase in energy consumption. The energy rebound effect offsets the scale of energy conservation as well. An empirical analysis of the energy rebound effect of the

Organisation for Economic Co-operation and Development (OECD) countries also showed that the rebound effect was less than 30%. Saunders and Tsao (2012) found out that global energy consumption brought only by lighting experiences to have a 100% rebound for 3 centuries across six continents and five technologies.

Shaozhou and Banban (2013) used a seemingly unrelated regression to estimate the impact of technology spillovers of FDI and international trade on energy intensity from 1998 to 2009 and concluded that technical spillover of FDI in the same industries can contribute to a decline in energy intensity. Similarly, Blomström and Kokko (1998) argued that FDI could lead to more intensive competition in the host country and force local firms to make more efficient use of existing resources or to find new resource technologies having competitive effects. Mielnik and Goldemberg (2002) analyzed the FDI and energy intensity of 20 developing countries and found that the increase of FDI could significantly reduce the energy intensity for which the technical spillover effect of FDI between different industries is the main reason for this. Consequently, FDI also brings different production factors in a region of the host country, whose flow in the geographical space leads to the spatial FDI spillover where the effect has a great influence on the economy, the environment, and energy not only in the host area but also in the surrounding areas. The technology changes brought by FDI could signify savings in energy. As researched by Dong et al. (2019), FDI had no direct impact on income inequality in the regions of the PRC between 2002 and 2015; the movement of labor will make energy savings possible. Besides, there will be bias if the domestic energy technology is already substantial, hence different environmental conditions and geography will also matter, while inducing energy savings technology from FDI.

Zhu et al. (2016) while researching the impact of FDI, economic growth, and energy consumption on carbon emissions in the Association of Southeast Asian Nations member states found through empirical evidence that an increase in energy consumption results in carbon emissions. Especially countries with large economies, a higher level of the population tends to reduce emissions, while an openness in trade can further decline in both big and small emissions nations. Del (2013) concluded that industrial agglomeration will promote successful spillover of FDI by analyzing the spillover impact of the European electricity sector. Lin and Kwan (2016) explored the extent of FDI spillovers in geographical space and spatial diffusion by using the data of the PRC companies and found out that domestic firms mainly benefit from FDI presence in their neighboring regions through spillovers of knowledge which entails wider scope in terms of geography.

Energy intensity convergence is also an interesting way to investigate how low energy efficiency levels in developing areas can match the high energy efficiency level in developed regions. Energy intensity convergence was observed in 18 industrial countries and 23 developing countries from 1971 to 1992, and convergence was pronounced as the GDP was measured by the purchasing power parity according to (Mielnik and Goldemberg 2000). Markandya et al. (2006) examined the convergence of energy intensity in 12 transition countries in Eastern Europe using the econometric model of adjustment lag, assuming that the convergence of energy intensity in these transition countries would exist from 2000 to 2020. The analysis of two-panel datasets in 111 countries from 1971 to 2006 and in 134 countries from 1990 to 2006 carried out by Liddle (2010) found out that both samples had persistent energy intensity convergence.

There also exists a major spatial dependence that is the spatial correlation between sample observations in one area and sample observations in other areas. Zhang and Zhou (2007) used a spatial autoregressive model to examine the spatial relationship between FDI and energy intensity, which showed that FDI has a significant spatial spillover effect and the effect significantly reduces energy intensity in the regions around the world. An empirical study by Zhou et al. (2012) on the spatial dependence, convergence, and influencing factors of interprovincial energy intensity from 2000 to 2009 also showed that the convergence speed of energy intensity significantly slowed down after 2005. The impact of FDI on energy intensity happened to be the most significant by comparing macro indicators such as state-owned economy proportion, GDP per capita, and urbanization with the industrial structure. The spatial econometric model was also applied by Yu (2012) to analyze the regional convergence of energy intensity in the PRC from 1998 to 2007 to find that there exists a beta convergence of provincial energy intensity after the spatial effects are controlled. Several issues were addressed and analyzed by Zhao et al. (2019) to show how FDI affects regional energy intensity in the host country from the perspective of factor reallocation. They tested the existence of energy intensity convergence while incorporating FDI by the spatial econometric model and drew the reason for the formation of energy intensity convergence considering the spatial dependence of the data.

Saboori et al. (2014) found a positive significant long-run bidirectional relationship between CO_2 emissions and economic growth, energy use in the road sector and economic growth, and CO_2 emissions and energy consumption in the road sector in all OECD countries by using a fully modified ordinary least squares (FMOLS) approach. The study by Al-mulali et al. (2013) explored how the electricity consumption from the renewable and nonrenewable sectors impact the economic growth in 18 Latin American countries by using the panel DOLS test. The results showed that there is a long-run positive effect on GDP growth in the investigated countries. One more important insight from this finding is that renewable electricity consumption revealed a more significant impact than nonrenewable electricity consumption in promoting economic growth in the investigated countries in the long-run and the short run. Our chapter extends this investigation by focusing on the relationships between FDI and energy efficiency improvements in South Asian countries.

7.3 Methodology and Data

7.3.1 Empirical Model

This study investigates the impact of FDI on industrial energy intensity by incorporating GDP per capita, industrial value-added, energy prices, and CO_2. Our study is inspired by earlier studies such as by Wu (2012), Adom and Kwakwa (2014), Wang (2017), Cao et al. (2020).These are some of the few studies that have used panel data for such investigations. The model for baseline panel regression is as follows:

$$EI_{it}^{m} = \beta_0 + \beta_1 EI_{i,t-1}^{m} + \beta_2 GDP_{it} + \beta_3 FDI_{it} + \beta_4 Enrprice_{it} + \beta_5 IVA_{it} + \beta_6 CO2_{it} + \gamma t_{it} + \varepsilon_{it} \tag{7.1}$$

here, i represents the country (i = 1, ……,4) and t represents the period (1990, … 0.2018). All variables are transformed into logarithmic, EI_{it}^{m} is a measure of industrial energy per unit of value-added output (industrial energy consumption to industrial value-added). The superscript *m* stands for nonrenewable and renewable energy intensity. GDP_{it} is the economic growth of per capita GDP in constant 2010 prices; FDI_{it} is the net inflow ratio of GDP; $Enrprice_{it}$ is an index of energy prices, which is measured using consumer price index (CPI); IVA_{it} is the size of manufacturing; $CO_{2_{it}}$ represents carbon emissions, and γt_{it} additional time trend effect. Furthermore, in Eq. (7.1) ε_{it} is called idiosyncratic error term, and we assume that the errors (ε_{it}) are independently and identically distributed *(i.i.d.)*. In other words, the idiosyncratic errors or time-varying errors follow the usual assumption of the standard normal distribution with zero mean and unit variance.

7.3.2 Panel Co-integration Test

A prerequisite for panel co-integration is that all variables should be integrated of order 1 at levels (I(1)). Then second, we use panel data for testing whether the variables are co-integrated or not in the long-run relationship. The Pedroni co-integration test proposes to allow for heterogeneous coefficient of intercepts and trend across cross-section. The popular procedures developed by Pedroni (1999, 2004) tests can be specified follows as:

$$y_{i,t} = \alpha_i x_{i,t} + z_{i,t}\psi_i + \varepsilon_{i,t} \tag{7.2}$$

where, i = (1,2,…,N) and t = (1,2,…,T) represent each country of South Asia and period of time in panel, respectively. The analysis focuses on the covariates in $x_{i,t}$ not being co-integrated. α_i, ψ_i and $\varepsilon_{i,t}$ indicate specific effects, deterministic trend and error term. The Pedroni panel co-integration consist of seven panel co-integration test among them four test are within-dimension and three includes between-dimension statistic. If the statistics fail to accept the null hypothesis of no co-integration, the variables to be co-integrated.

Kao panel co-integration test also followed the same basic principles of Pedroni but it identifies cross-section specific intercept and homogeneous coefficient. Kao (1999) proposes the Augmented Dickey-Fuller regression as below:

$$\hat{\mu}_{i,t} = \rho\hat{\mu}_{i,t-j} \sum\nolimits_{j=1}^{p} \rho_j \Delta\hat{\mu}_{i,t-j} + \pi_{i,t} \tag{7.3}$$

where, ρ indicates the number of lagged difference terms. Notably, the Augmented Dickey-Fuller test for the Kao (1999) test, a standard normal distribution must be converted into *N(0, 1)*.

7.3.3 *Panel FMOLS and DOLS Estimation for Long Run*

This chapter proceeds to estimate Eq. (7.1) applying two models FMOLS and DOLS method based on OLS estimators following numerous previous studies apply that the existence of co-integrating among the variables. This technique's main advantage is on its ability to correct for both autocorrelation and simultaneity bias. FMOLS allows for the correction of Newey-West, while DOLS allows the addition of more lagged and lead variables. Pedroni (1996, 2001) specified the following equation to estimate long-run coefficient.

$$\beta^{*}_{FMOLS} = \frac{1}{N}\sum\nolimits_{i=1}^{N}\left[\left(\sum\nolimits_{t=1}^{T}(x_{it}-\overline{x}_i)^2\right)^{-1}\left(\sum\nolimits_{t=1}^{T}(x_{it}-\overline{x}_i)y^{*}_{it}-\Gamma\hat{\lambda}_i\right)\right] \tag{7.4}$$

in which,

$$y^{*}_{it} = (y_{it}-\overline{y}_i) - \left(\widehat{\Omega}_{21i}/\widehat{\Omega}_{22i}\right)\Delta x_{it}$$

and $\hat{\lambda}_i$ indicates as

$$\hat{\lambda}_i = \widehat{\Gamma}_{21i} + \widehat{\Omega}^{0}_{21i} - \left(\widehat{\Omega}_{21i}/\widehat{\Omega}_{22i}\right)\left(\widehat{\Gamma}_{22i}+\widehat{\Omega}_{22i}\right)$$

here, Ω and Γ refer to as asymptotic covariance matrix for long-run variance and dynamic covariance. Then, DOLS estimator is specified as below:

$$y_{it} = \beta^{*}_{it} + \sum\nolimits_{j=-q}^{q}\gamma_{ij}\Delta x_{i,t+j} + \xi_{1i}D_{1i} + \varepsilon_{it} \tag{7.5}$$

where, q is defined as the numbers of chosen lag for the models. Kao and Chiang (2000) are then applied to DOLS estimator for the use of the finite sample properties.

7.3.4 Panel Granger Causality Test

Granger (1988) claims that if two or more variable co-integrated, there must be at least one-way causality. Although the Pedroni co-integration test examines whether the data are co-integrated or not, it does not provide the direction of causality. Therefore, Granger causality based on the vector error correction model (VECM) is capable of capturing the short-run causality based on the F-statistics and the long-run causality based on the ECT_{t-1} model of lagged error correction. We adopt the causality of Granger in the VECM model suggested by Engle and Granger (1987) for this reason:

$$\begin{bmatrix} \Delta TIEI_{it} \\ \Delta GDP_{it} \\ \Delta FDI_{it} \\ \Delta Enrprice_{it} \\ \Delta IVA_{it} \\ \Delta CO_{2it} \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{bmatrix} + \sum_{n-1}^{r} \begin{bmatrix} \alpha_{11n} & \alpha_{12n} & \alpha_{13n} & \alpha_{14n} & \alpha_{15n} & \alpha_{16n} \\ \alpha_{21n} & \alpha_{22n} & \alpha_{23n} & \alpha_{24n} & \alpha_{25n} & \alpha_{26n} \\ \alpha_{31n} & \alpha_{32n} & \alpha_{33n} & \alpha_{34n} & \alpha_{35n} & \alpha_{36n} \\ \alpha_{41n} & \alpha_{42n} & \alpha_{43n} & \alpha_{44n} & \alpha_{45n} & \alpha_{46n} \\ \alpha_{51n} & \alpha_{52n} & \alpha_{53n} & \alpha_{54n} & \alpha_{55n} & \alpha_{56n} \\ \alpha_{61n} & \alpha_{62n} & \alpha_{63n} & \alpha_{64n} & \alpha_{65n} & \alpha_{66n} \end{bmatrix} \times \begin{bmatrix} \Delta TIEI_{it} \\ \Delta GDP_{it} \\ \Delta FDI_{it} \\ \Delta Enrprice_{it} \\ \Delta IVA_{it} \\ \Delta CO_{2it} \end{bmatrix}$$
$$+ \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} \eta_{it1} \\ \eta_{it2} \\ \eta_{it3} \\ \eta_{it4} \\ \eta_{it5} \\ \eta_{it6} \end{bmatrix} \tag{7.6}$$

where Δ refers to first difference operator, *i* denotes (1,…, 4 South Asian countries) cross section and *t* denotes (1990,…, 2018) period of time, ECT_{t-1} indicates lagged error correction term procedure obtain from long-run and η_{it} refers to the error term.

7.3.5 Data

This study uses annual data on industrial energy intensity and foreign direct investment for the South Asian countries. The panel data set in each country flows over 28 years (1990–2018). The eight countries in the South Asian region are Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.

However, due to a lack of data availability, we only consider Bangladesh, India, Pakistan, and Sri Lanka for our analysis.

Industrial energy consumption is measured by energy use in tons of oil equivalent, collected from the balances database provided by the International Energy Agency (IEA). Numerous studies mentioned two types of energy efficiency: the single factor energy efficiency and total factor energy efficiency. The single factor energy efficiency is a conventional measurement of economic energy efficiency, which is also represented as energy intensity. Energy intensity (EI) has used as a potential indicator of energy efficiency (EE), calculated as the ratio of industrial energy consumption to the industrial value-added (Elliott et al. 2013; Zhang 2017; Akram et al. 2020). Following Luan et al. (2020), this chapter considered a proxy for the EE variable by industrial value-added output per unit of industrial energy consumption, which is opposite to energy intensity. Real GDP per capita is measured in constant 2010 $ (GDP). Due to the unavailability of energy prices data, we used the consumer price index (CPI 2010 = 100) as a proxy variable following earlier studies by Sadorsky (2010) and Doytch and Narayan (2016), and the industrial value-added is expressed as a ratio of GDP, these data are extracted from the World Development Indicators (WDI) database. Data for FDI, FDI inflows as a ratio of GDP in current $ are collected from the United Nations Conference on Trade and Development (UNCTAD) database. Figure 7.1 shows the foreign direct investment inflows in the South Asian countries. Figure 7.1 depicts that India received high FDI compared to the counterpart countries. Furthermore, carbon emissions (CO_2) are measured in metric tons per capita, which is taken from the various publications of the International Energy Agency (IEA). Table 7.1 provides the definitions, measurement, and sources of selected variables.

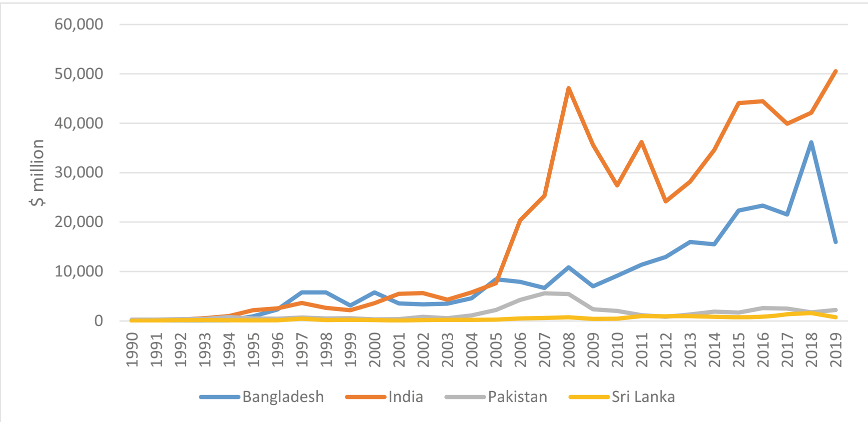

Fig. 7.1 Foreign direct investment. *Source* United Nations Conference on Trade and Development

Table 7.1 Description and measurement of variables

Variable	Definitions and measurement	Sources
Total industrial energy intensity (TIEI)	Total industrial energy consumption toe/industrial value-added	International Energy Agency (IEA)/World Development Indicators (WDI)
Industrial nonrenewable energy intensity (INonRenEI)	Industrial nonrenewable energy consumption toe/ Industrial value-added	International Energy Agency (IEA)/World Development Indicators (WDI)
Industrial renewable energy intensity (IRenEI)	Industrial renewable energy consumption toe/Industrial value-added	International Energy Agency (IEA)/World Development Indicators (WDI)
Real GDP per capita (GDP)	Constant (2010 $)	World Development Indicators (WDI)
Foreign Direct Investment (FDI)	Foreign direct investment (current $)/gross domestic product (current $)	United Nations Conference on Trade and Development (UNCTAD)/WDI
Energy prices (Enrprice)	Consumer price index (2010 = 100)	World Development Indicators (WDI)
Industrial value-added (IVA)	Industrial value-added/gross domestic product	World Development Indicators (WDI)
Carbon emissions (CO_2)	Carbon emissions (metric tons per capita)	International Energy Agency (IEA)

Sources All data were collected from the World Development Indicators (WDI), the International Energy Agency (IEA), and the United Nations Conference on Trade and Development (UNCTAD) databases

7.4 Empirical Results

7.4.1 Panel Unit Root Test

In the first step of our analysis, we apply panel unit root tests (Levin et al. 2002; Breitung 2001; Im et al. 2003; Maddala and Wu 1999) to examine the stationary data. The results of the panel unit root tests are reported in Table 7.2, which shows that all variables are not significant at the levels. Hence, the null hypothesis of the series cannot be rejected implying that the series are not stationary at the levels. At the first difference, however, all the variables are significant. Therefore, at the first difference the variables are stationary, resulting in the rejection of null hypothesis, which confirms that the series are integrated of order one for all series at the levels.

7.4.2 Results of Co-integration

We proceed to apply co-integration tests to figure out a long-run relationship among the variables since having confirmed the order of integration that all variables are

Table 7.2 Panel unit root test

Variables	LLC		Breitung		IPS		Fisher-ADF	
	Level	First Diff.	Level	First Diff.	Level	First Diff.	Level	First Diff.
TIEI	–0.50	–4.82***	–1.21	–3.86***	–1.11	–7.28**	12.81	55.64***
IRenEI	–1.07	–7.33***	–0.79	–3.79**	–1.39	–7.18***	6.90	54.49***
INonRenEI	–0.58	–5.18***	–0.24	–1.02*	–1.34	–7.58***	13.94	105.62***
FDI	–0.67	–4.22***	–0.61	–1.46*	–0.90	–7.42***	13.34	119.52***
Enrprice	–0.03	–2.58**	–1.16	–3.34***	–1.75	–2.49**	2.95	19.01**
GDP	0.51	–5.67***	–0.49	–3.97***	1.43	–4.31***	3.44	45.62***
CO_2	–0.19	–4.52***	–1.88	–4.69***	–1.26	–7.80***	7.58	58.09***
IVA	–0.99	–3.49***	–0.75	–5.24***	–0.50	–5.32***	3.83	88.08***

Note: ***, ** and * indicate 1, 5% and 10% level of significance, respectively. *Source* Authors' calculation

stationary at first difference. Three types of panel co-integration test are employed in this study, namely, Pedroni (1999, 2004) and Kao (1999) tests. The results of Pedroni test in Table 7.3 indicate that five statistics are significant at the 5% level and one statistic is significant at the 10% level out of seven test statistics. Hence, it failed to accept null hypothesis of no co-integration. We can conclude that there is 2012 presence of a long-run relationship indicating that industrial energy intensity bears a long-run relationship with FDI, economic growth, energy prices, industrial value-added, and carbon emissions. The Kao co-integration test results also show that rejected null hypothesis of no co-integration, which seems to be significant at 1% level, and confirm the existence of a long-run relationship among the variables.

7.4.3 Panel Estimation Results

This study used FMOLS for heterogeneous and DOLS for homogeneity co-integrated panel is estimated to examine the long-run equilibrium relationship

Table 7.3 Panel co-integration tests by Pedroni (1999, 2004)

Panel (within dimension)			Group (between dimension)		
Statistics	Value	Prob	Statistics	Value	Prob
Panel v-Statistic	0.19096	0.424			
Panel rho-Statistic	1.84*	0.063	Group rho-Statistic	0.898	0.816
Panel PP-Statistic	–1.826**	0.033	Group PP-Statistic	–1.789**	0.036
Panel ADF-Statistic	–1.827**	0.034	Group ADF-Statistic	–1.831**	0.034
panel co-integration tests by Kao (1999)					
ADF	–3.139***	0.001			

Note: ***, ** and * indicate 1, 5%, and 10% level of significance, respectively. *Source* Authors' calculation

Table 7.4 Panel long-run estimation of total industrial energy intensity

Long-run coefficient dependent variable total industrial energy intensity				
Variable	FMOLS		DOLS	
	Coefficient	t-statistic	Coefficient	t-statistic
GDP	–0.939***	–7.063	–0.840***	–3.616
FDI	–0.018**	–2.210	–0.026**	–2.352
Enrprice	–0.097**	–2.468	-0.103***	–2.358
IVA	0.829***	5.012	0.842**	2.873
CO_2	0.917***	7.898	0.819***	3.993
t	–0.053***	3.734	–0.063***	3.471

***, ** and * indicates 1, 5%, and 10% level of significance, respectively. *DOLS* dynamic ordinary least square, *FMOLS* fully modified ordinary least square. *Source* Authors' calculation

after confirming that the panel is co-integrated. Firstly, we disaggregated industrial energy intensity into nonrenewable, renewable, and total industrial energy intensity. The results of Table 7.4 show the long-run estimates parameter based on Eq. (7.1) using the FMOLS and DOLS techniques. The coefficient of income, energy prices, and foreign direct investment are negatively and highly significant at the 1% and 5% level, respectively. A 1% increase in income reduces industrial energy intensity by 0.939%, endorses an income-induced improvement in energy intensity in the South Asian countries. Furthermore, FDI and energy prices also reduce total industrial energy intensity by 0.018% and 0.097%, respectively in each specification. This indicates that the increase in foreign direct investment will result in the reduction industrial energy intensity in the South Asia countries. One reason for this finding is FDI can promote economic activity, via the transfer of technology and diffusion, spillover effects, increased productivity, and managerial skills. Furthermore, according to the "law of diminishing marginal returns" (Lv et al. 2020), a rise in energy prices improves energy efficiency. This suggests that higher energy prices will lead to the adoption of energy-efficient technology, at least by the wealthy, but will reduce the energy use by the poor. Therefore, income, FDI, and energy price play a crucial role in reducing industrial energy intensity, these suggest that declining industrial energy intensity is purely due to an improvement in energy efficiency. Previous studies, interestingly, also find the impact of FDI on energy intensity (Adom 2015; Cao et al. 2020; Luan et al. 2020; Pan et al. 2020). Our result is consistent with Wu (2012), Chen et al. (2019), and Luan et al. (2020) in terms of energy prices. However, industrial value-added and carbon emissions are positively associated with total industrial energy intensity and are statistically significant. A 1% increase in industrial value-added increases by 0.829%, indicating that industrial value-added increases the industrial energy intensity. Thus, the promotion of energy efficiency in industrial energy consumption should be encouraged. CO_2 emissions have a positive significant association with industrial energy intensity. Autonomous technology change (*t*), also has a negative influence on industrial energy intensity.

Table 7.5 Panel long-run estimation of non-renewable industrial energy intensity

Long-run coefficient dependent variable non-renewable industrial energy intensity				
Variable	FMOLS		DOLS	
	Coefficient	t-statistic	Coefficient	t-statistic
GDP	–0.549**	–2.717	–0.515*	–1.844
FDI	–0.024	1.334	0.012	0.491
Enrprice	–0.127**	–2.131	–0.114**	–2.415
IVA	1.040***	4.132	0.937**	2.662
CO_2	0.418**	2.368	0.392	1.590
T	–0.062***	4.386	–0.064***	4.283

Note: ***, ** and * indicate 1, 5%, and 10% level of significance, respectively. *DOLS* dynamic ordinary least square, *FMOLS* fully modified ordinary least square. *Source* Authors' calculation

Results from Table 7.5 reveal that the elasticity of income and energy prices have a negative impact on nonrenewable industrial energy intensity. FDI on nonrenewable industrial intensity is negative but insignificant. A 1% increase in income and energy prices lowers the nonrenewable industrial energy intensity by 0.549% and 0.127%, respectively. Income and energy prices play an important role to reduce nonrenewable industrial intensity since energy prices are also sensitive to restrict the use of nonrenewable energy. However, industrial value-added has a positive influence on nonrenewable industrial energy intensity. The coefficient of industrial value-added is estimated to be 1.04, implying that a 1% rise in industrial value-added induces a 1.040% increase in nonrenewable industrial energy intensity. Moreover, carbon emissions are positively associated with nonrenewable industrial energy intensity.

Results from Table 7.6 reveal that income, FDI, and energy prices have a negative coefficient and statistically significant association with renewable industrial energy intensity. The coefficient of income is (–1.254) association with renewable industrial energy intensity: indicating that South Asian nations are experiencing higher economic growth and adopting technology advancement, as a

Table 7.6 Panel long-run estimation of renewable industrial energy intensity

Long-run coefficient dependent variable renewable industrial energy intensity				
Variable	FMOLS		DOLS	
	Coefficient	t-statistic	Coefficient	t-statistic
GDP	–1.254***	–8.767	0.623**	2.017
FDI	–0.080***	–6.372	–0.009	–0.449
Enrprice	–0.184***	–4.344	–0.587**	–2.216
IVA	1.236***	6.947	0.580*	1.893
CO_2	1.358***	10.865	0.356**	2.852
T	–0.031	1.185	–0.036*	1.758

***, ** and * indicate 1, 5%, and 10% level of significance, respectively. *DOLS* dynamic ordinary least square, *FMOLS* fully modified ordinary least square. *Source* Authors' calculation result countries with a higher energy efficiency (i.e., reduction in energy intensity). However, industrial value-added has a positive significant association with renewable industrial energy intensity. A 1% increase in industrial value-added leads to a 1.236% rise in renewable industrial energy intensity. We also use time trend variables to capture and address the impacts of technology transfer to renewable energy intensity. The estimated coefficient time trend variable is a negative and statistically significant with renewable industrial energy intensity. This suggests that income, FDI, and energy price play a critical role to improve energy efficiency. Governments should discourage subsidies schemes on energy use to provide entry incentives to foreign firms.

7.4.4 Panel Granger Causality Test

The existence of panel co-integration between industrial energy consumption, economic growth, foreign direct investment, energy prices, industrial value-added, and carbon emissions confirms the existence of a long-run equilibrium relationship among the variables although the nature and direction of causality is still unclear. Thus, we employed the Granger causality test based on the VECM system to estimate the nature and direction of causality among the variables. Table 7.7 shows the short-run and long-run Granger causality test results.

The one period lagged error correction (ECT_{t-1}) is significant at the 10% level in industrial energy intensity and energy price and industrial value-added equations.

Table 7.7 Panel VECM Granger causality test

Dep. variable	Direction of causality						
	Short-run						Long-run
	$\Delta TIEI$	ΔGDP	ΔFDI	$\Delta Enrprice$	ΔIVA	ΔCO_2	ECT_{t-1}
$\Delta TIEI$		0.419	5.420**	0.189	1.025	0.032	−0.024*
		(0.517)	(0.019)	(0.365)	(0.311)	(0.858)	[−1.916]
ΔGDP	0.059		0.005	0.021	1.398	0.036	0.009
	(0.807)		(0.946)	(0.884)	(0.237)	(0.848)	[2.683]
ΔFDI	10.420***	6.867**		0.253	1.047	1.985	−0.252***
	(0.001)	(0.009)		(0.615)	(0.306)	(0.158)	[−7.201]
$\Delta Enrprice$	0.089	0.263	1.245		1.524	0.557	−0.002*
	(0.746)	(0.608)	(0.264)		(0.217)	(0.455)	[−1.669]
ΔIVA	5.762**	5.116**	0.348	7.715**		1.352	−0.008*
	(0.016)	(0.024)	(0.555)	(0.005)		(0.245)	[−1.835]
ΔCO_2	3.931*	5.884**	0.716	0.011	1.231		0.004
	(0.047)	(0.015)	(0.397)	(0.917)	(0.267)		[−0.931]

***, ** and * indicate 1, 5% and 10% level of significance, respectively and parenthesis and bracket represent *p-value* and *t-statistics VECM* vector error correction model. *Source* Authors' calculation

Furthermore, the FDI equation is significant at the 1% level. This reveals that there is a bidirectional Granger causality between industrial energy intensity and foreign direct investment, industrial energy intensity and energy price, and industrial energy intensity and industrial value-added. This results show the causality between industrial energy intensity and FDI, implying that the feedback hypothesis exists in the South Asian countries. Industrial energy intensity causes FDI and vice versa. Additionally, there is unidirectional Granger causality running from economic growth, carbon emissions to industrial energy intensity. However, ECT_{t-1} is not significant for the economic growth and carbon emissions equations. The speed of adjustment toward forming a long-run equilibrium relationship from the error correction model provides robust evidence of co-integration to our Pedroni co-integration results.

In the short run, we find a bidirectional Granger causality between industrial energy intensity and foreign direct investment. In addition, there is a unidirectional causality running from industrial energy intensity to industrial value-added and carbon emissions. Furthermore, a unidirectional Granger causality running from income to FDI and CO_2 in South Asian countries.

7.5 Conclusions and Policy Recommendations

This study examines the impact of FDI on total industrial energy intensity, renewable and nonrenewable industrial energy intensity. Our study is notable as only a few studies have investigated the effect of FDI on industrial energy intensity in the past. Unlike previous studies, we use only industrial energy intensity for resource-rich South Asian countries. To our knowledge, no studies so far have been conducted in South Asian countries. We relied on the historical datasets from 1990 to 2018 and applied a panel analysis technique for FMOLS and DOLS approaches to reveal several findings. Our results from heterogeneous panel co-integration documents that there is the presence of a long-run equilibrium relationship between industrial energy intensity and economic growth, foreign direct investment, energy prices, industrial value-added and carbon emissions.

Our empirical results conclude that FDI reduces industrial intensity in South Asian countries in both total and renewable industrial energy intensity. Furthermore, income and energy prices also lower the industrial energy intensity. This indicates that FDI, income, and energy prices are a primary motivation to promote energy efficiency. However, industrial energy intensity and carbon emissions increase the industrial energy intensity. The results from the panel vector error correction model (VECM) reveal that a bidirectional causality exists between industrial energy intensity and foreign direct investment. This confirms that a feedback hypothesis between industrial energy intensity and FDI. The results also find that a unidirectional causality from economic growth and carbon emissions to industrial energy intensity in the long-run. In the short-run, the chapter finds that there is the two-way causal relationship between industrial energy intensity in the

South Asian countries. Furthermore, a causal relationship exists from industrial energy intensity to industrial value-added and CO_2 and from economic growth to FDI and CO_2.

The findings of this study have significant policy implications for the South Asian countries. Our findings show the evidence of causal relationship between total industrial energy intensity (TIEI) and FDI, TIEI and income, and TIEI and energy prices, indicating that more efficient energy use will promote growth by improving energy efficiency. South Asian countries should reinforce FDI inflow through strategic reforms in renewable energy sectors and increase local availability for energy conservation spillovers. Despite the FDI flows, it seems that FDI so far has brought green-energy advancing practices that have reduced the use of non-renewable energy in the South Asian countries. However, there is no link between FDI and renewable energy sources. Improving energy efficiency is a main driver of sustainability policies globally. So, energy efficiency policies should be implemented for a sustainable development, environmental benefits, improving energy efficiency will lead to long-term growth gains. Finally, South Asian countries should cooperate together to encourage cross-border trade of technology diffusion that improves energy efficiency.

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Chapter 8
The Effect of Global Value Chain Participation and Position on Energy Efficiency in Belt and Road Countries

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Abstract The Belt and Road Initiative (BRI) by the People's Republic of China, (PRC) has been noted by several scholars to be a massive project aimed at enhancing the Eurasian trade network. Some stakeholders have noted that the program appears to be altruistic. Although partner countries and the PRC both stand to gain from the program, it still leaves doubt in some scholars' minds about the PRC's main aim. This, to a large extent, could be one major factor why some European countries were slow to accept the program. However, it does not negate the fact that the program came when several European countries were in search of investments to lift their economies. The current study seeks to add to the pioneering body of literature on the BRI by focusing on a sample of 36 European countries and evaluating their global value chain (GVC) participation and positions before and after the BRI, and the impact on energy efficiency investment. The result shows an even GVC participation by most European countries before the BRI. There were negative and positive position indices of the GVCs after the BRI with a negative dominance. The dominant negative positions could be as a result of the initiative still being in its early stages; considering that a number of European countries were slow to adopt the BRI projects. The result showed no statistically significant prediction of the GVC participation in energy efficiency investment both before and after the BRI. The chapter provides policy recommendations on fostering the energy efficiency and green investments in BRI European countries.

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8.1 Introduction

The Belt and Road Initiative (BRI) aims to integrate the Silk Road Economic Belt and the 21st Century Maritime Silk Road. It routes through Central Asia to Europe, West Asia through the Persian Gulf, and the Indian Ocean to South Asia. The BRI sees energy infrastructure and transport as top priorities and stresses the importance of climate change on infrastructure development. As a result, energy efficiency (EE) has received significant investments under the BRI initiative in the selected European countries. These investments have, however, yielded mixed results on EE for these countries.

Furthermore, the global value chain (GVC) has a direct link to these countries' energy performance, given that these countries under the BRI have received a more generous amount of energy investments from companies in the People's Republic of China (PRC). Besides, the BRI has equally stressed the importance of renewables and energy efficiency to ensure sustainable energy consumption. The advances in technology, transportation, distribution, and communication have been significant for decades (Orlic 2017; Taglioni and Winkler 2016). This has spurred policy liberalization strategies, which now underpin countries' development strategies worldwide (Liu et al. 2018; Taglioni and Winkler 2016). This is closely tied to how trade is conducted across the world now. There is currently a need to share knowledge, information, and expertise (Gereffi and Fernandez-Stark 2011; Kersan-Škabić 2019). This has engendered the need to fragmentize production across countries, known as GVCs. GVCs are made up of fragmented production and processing segmentation in different phases that occur in several locations in different countries (Gereffi & Fernandez-Stark 2011; Kersan-Škabić 2019).

According to Jingzi et al. (2013) the GVC is a phenomenon that cannot be taken for granted. It was indicated that in recent times, discussions on GVCs have been in the fabric of almost all countries, from developed to less developed countries. GVCs are recognized to comprise activities that cut across raw material and components procurements, manufacturing, and distribution. However, for this to happen smoothly, there is a need to reduce the obstruction to the flow of products, information, and capital (Jingzi et al. 2013).

Participation and positioning of countries in GVCs offer deprived and rich economies the opportunity to exploit a comparative advantage in a more articulated manner, while customers benefit from lower prices and improved variety (Leitner and Stehrer 2014; Orlic 2017). To capture such prospects and to consolidate alliances and improve security, policy makers in the PRC, the European Union (EU), and the United States, have stimulated economic integration in their regions (Leitner and Stehrer 2014; Solmecke 2016; Taglioni and Winkler 2016; UNCTAD 2013).

The BRI was launched in 2013 by the president of the PRC, Xi Jinping, as a transcontinental long-run policy framework and investment tool to boost infrastructure investment and fast track economic coupling of countries similar to the bygone years of the Silk Road initiative. The funding emanates from state-run banks, policy banks, state-owned funds, and international financing institutions. The vision is to develop infrastructure to $6 trillion across many countries (Zhou et al. 2018). The issue of PRC investments in energy projects like power plants and transport infrastructure can lock in new technologies and contribute to CO_2 emissions. Thus, the PRC invested about $3.4 billion in renewable energy and energy generation for BRI countries from 2014–2017 (Zhou et al. 2018). Realizing the importance of EE on the BRI countries, an empirical work by Liu (2020) on income inequality impact on EE of 33 BRI countries for 2000–2016 revealed the overall EE of the study countries is as low as 0.38. The high-income countries had a better EE ratio, while others experienced a U-shape effect on EE and other groups experienced an inverted U-shape effect on EE.

The BRI, among other aims, seeks to improve infrastructure development and connectivity and stimulate economic integration across countries in the Eurasian zone (Ghiasy and Zhou 2017). The BRI is a unique project as it has an outlook that is more altruistic but wrapped around a mutually beneficial mindset, with a great deal of flexibility (Ghiasy and Zhou 2017; Solmecke 2016). Of course, this phenomenon has not gone without doubt from various stakeholders, including those in the Eurasia zone (Ghiasy and Zhou 2017).

Arguably, after the introduction of the BRI in 2013, it has been regarded as one of the largest and most determined, and ambitious global connectivity initiative in recent times with an underpinning that is a central aspect of the PRC's foreign policy strategy as well as geopolitical vision (Chen 2018; Kohl 2019). The initiative's introduction and implementation have connected many countries, regions, and continents (Chen 2018; Solmecke 2016; Wang 2015). The PRC promotes the BRI as one of its critical economic policy strategies to revive the traditional Silk Road to offer connectivity in diverse forms, mostly through large-scale infrastructure investments (Solmecke 2016). After 6 years of its introduction and adoption by some countries, the BRI has still not seen a unified approach from geographical Europe and EU member states, although most EU member states have considered it.

With the significant engagement of EU member states, the European Bank for Reconstruction and Development (EBRD), and the European Investment Bank (EIB), significant EU members have become part of the strategy (Ghiasy and Zhou 2017). However, it was not until 2015 that most European countries signaled substantial and significant interest, which has grown with many EU member states adopting the BRI strategies (Le Corre 2018). Le Corre (2018) reported that after March 2015, over 14 EU member states decided to be part of the BRI strategy. With the apparent participation of some countries in Europe, it becomes vital to examine how the BRI has influenced the GVC participation and position of some selected European countries and if this has influenced their energy efficiency investment.

This chapter outlines the importance of the GVC and its position on EE improvements in the European BRI countries. EE is vitally important as most of the BRI projects in the energy and transport sectors tend to lock in emerging technologies and exacerbate climate change impacts. For this situation to be lessened, there is the need to ramp up investments in EE and green technologies to ensure the transition to a low carbon future (Rasoulinezhad and Taghizadeh-Hesary 2020). Few researchers have addressed the problem of GVC on EE in the European BRI countries. This study aims to fill this devoid by diving into the causal factors militating against or impacting on EE in these countries. For instance, (Cuiyun and Chazhong 2020) evaluated the green development levels of 49 countries in 2015 along the BRI and opined the importance the PRC government places on promoting green BRI ecological and environmental cooperation plans. Also, Liu et al. (2020) studied income inequality and its effects on EE on 33 BRI countries, as well as Qi et al. (2019) who researched EE among BRI and to see the trends of how countries are faring in their bit to promote EE.

On the other hand, (Sun et al. 2020a) analyzed 48 BRI countries' EE performance and found no convergent traces among the study countries. Despite all these researched papers, they have not dealt with the issue of investments in renewable energy and EE deployment in BRI countries. Thus this is the novelty of our study. We seek to analyze GVC participation and position on EE in the BRI countries.

We hope that our research will help demystify the myth surrounding the GVC participation and position in investment in EE. If the world is to achieve the Paris Accord by 2030, EE deployment and, for that matter, green development must be given serious attention. It is suggested that substantial financial and regulatory support on EE be extended to the BRI countries and introducing green finance instruments (Taghizadeh-Hesary and Yoshino 2019, 2020; Sun et al. 2020b). Selecting the right infrastructure investment tool is critical to eliminating poverty in the BRI countries and achieving the related Sustainable Development Goals (SDGs).

The following part is organized as follows. Section 8.2 gives a literature review, and Sect. 8.3 describes the methodology. Section 8.4 has the results of the analysis, and Sect. 8.5 concludes and provides policy recommendations.

8.2 Literature Review

8.2.1 Energy Efficiency Financing

EE financing has gained significant attention from several BRI countries. As such, policies have been formulated and implemented such as green bonds, where the proceeds are used toward increasing EE deployment. Green bonds are seen as a policy instrument to leverage global investment opportunities for tackling the climate menace. However, the sector is nascent, particularly in emerging markets, making up less than 0.2% of bonds issued worldwide and less than 2% in China (Climate Bonds Initiative and China Central Depository and Clearing Co Inc. 2016; Banga 2019). The People's Bank of China (PBOC) projects that the PRC will need around CNY 2 trillion per annum (Kidney and Oliver 2014) to tackle climate change and environmental challenges. For instance, Mexico has subsidies for EE and minimum performance standards (Retallack et al. 2018). Multilateral development banks (MDBs) catalyze to maximize the needed finances to combat climate change mitigation. In 2015, the MDBs spent 14% of their EE's financial commitments, which is $2.9 billion (Retallack et al. 2018). There is space for further investment opportunities in EE, given the potential for unlocking decent jobs and, at the same time, working to improve investments in the sector. Furthermore, a major investment facility from the EBRD called sustainable energy finance facilities (to reduce the energy intensity of 22 European and North African countries and encourage EE), has helped in reducing 4Mt CO_2, resulting in the spending of over €2.8 billion (Retallack et al. 2018). Forrester and Reames (2020) looked at the energy efficiency financing coverage gap in Michigan, USA. They found that an energy efficiency financing coverage gap exists for moderate income households. Their results show that 12% of Michigan households fall into the energy efficiency financing coverage gap. Michigan counties' coverage gaps ranged from 0 to 24%. Households with low incomes need higher credit scores for loan approval. Sarkar and Singh (2010) draw on selected experiences with financing energy efficiency in developing countries to explore the key factors of various programmatic approaches and financing instruments that have been applied successfully for delivering energy efficiency solutions. Their results show that with adequate liquidity in major developing country markets and the availability of modern energy savings technologies, it is often the institutional issues that become a key challenge to be addressed in order to finance and implement robust programs. As further operational experience is gained, increased knowledge sharing can lead to a scaling-up of such energy efficiency investments.

8.2.2 Global Value Chains

According to Gereffi and Fernandez-Stark (2011) the global economy is closely tied to GVCs, an indicator of international trade, global gross domestic product (GDP), and employment. Countries relying on each other with regards to the production of goods have been in existence for years, as countries have depended on others for components for productions over the years (Taglioni and Winkler 2016). The difference, however, under the GVC framework is differentiated by four main characteristics: customized production, sequential production decisions from buyers to the suppliers, expensive contracting costs, and global matching of goods and services with production teams and ideas (Antràs 2015; Taglioni and Winkler 2016).

Under GVCs, goods and services are usually produced in line with a certain specification in mind, which is informed by what the buyer wants (Taglioni and Winkler 2016). Customization results from sequential production and sales decisions from buyers to the producers (Taglioni andWinkler 2016). As a result of different legal authorities in the different countries involved in the GVC web, there is usually the need for a comprehensive contract between parties. This binding contract is also associated with the binding of production teams from different countries globally (Taglioni and Winkler 2016). According to Taglioni and Winkler (2016) this can result in the transfer of knowledge and skills at an accelerating rate, one that does not exist under the traditional mode of production. However, this can also result in income only being centered on countries associated with the GVCs, which can be detrimental to the growth of those that are part of the GVCs (Taglioni and Winkler 2016).

The fragmentation nature of GVCs, which promotes the participation of different firms at the different circle of production, has given the opportunity of individual small and medium firms to collaborate with multinational firms, allowing them to gain access to a global market, one that might not have been possible under the traditional mode of production (Mettler and Williams 2011; Orlic 2017; Taglioni and Winkler 2016). However, this does not mean that it is a comfortable ride as competition is usually fierce for spots in the GVCs (Taglioni and Winkler 2016). This is also coupled with complex trade-off policies, which expose firms to uncertainties that are associated with coordinating production across several locations (Taglioni and Winkler 2016).

Studies have indicated that in as much as there are many benefits associated with GVCs, the underlining fact is that there are winners and losers. Looking at the study carried out by Stollinger (2016) it was established that there is no uniform benefit with regards to GVC participation, as it was established that manufacturing activities in the EU, are more centered in Central Europe, who are increasingly benefiting from structural change toward manufacturing.

According to Kersan-Škabić (2019) countries in the EU have different values of GVC participation. For example, Luxembourg and Slovakia have the highest participation values, while Croatia has the lowest (Kersan-Škabić 2019). The performance of a country regarding their GVC performance in the EU does not heavily rely on the duration of their membership in the union. From the evidence put forward by Kersan-Škabić (2019) some new members in the EU have achieved impressive interconnection with foreign partners, with GVC participation that can compete with some of the EU-15, in fact, some of the so-called newcomers have higher GVC participation (Kersan-Škabić 2019). (The EU-15 are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom). The newcomers include Slovakia, Hungary, and the Czech Republic. However, countries like Croatia and Cyprus have shallow GVC participation values (Kersan-Škabić 2019; OECD 2019).

The study carried out by Orlic (2017) unlike those carried out by Kersan-Škabić (2019) focused on GVC participation regarding the microeconomic data. Orlic's study relied on data from the fifth edition of Business Environment and Enterprise Performance Surveys (BEEPS). New member states include potential countries in the Southeast Europe region, excluding Kosovo. In total, 1,223 companies were sampled from 21 manufacturing industries. The study showed that perception matters in GVCs for firms. It was indicated that when foreign players perceive that a firm has international certification and access to bank credit, they tend to believe in the firm's ability to meet the required quality and to have the ability to deliver. This to a large extent, results in differences in GVC participation.

Leitner and Stehrer (2014) posited that new member states and EU15 countries benefit differently from GVC participation. According to Leitner and Stehrer (2014) new member states benefit the most from more vigorous trade expansion, and the EU-15 benefit more from vertical specialization. Also, the new member states predominantly specialize in activities that are related to assembling, while EU-15 countries are more centered in higher GVC productions.

Regardless of the difference in GVC participation, the EU's role as a whole in GVCs cannot be underestimated. According to Leitner and Stehrer (2014) the EU has firmly integrated into the world economy and is one of the key global players and trading partners (Leitner and Stehrer 2014). Leitner and Stehrer (2014) posited that the EU accounts for about 40% of global merchandise trade.

8.2.3 Belt and Road Initiative

The PRC has shown that fighting climate change does not inhibit economic growth. Thus, the PRC has instituted measures to couple greening its finances and investment instruments overseas (especially in BRI countries) and home. The government has made green finance a significant issue under the BRI initiative and has instituted the Guiding Opinions on Promoting the Green BRI and the Belt and Road Ecological and Environmental Cooperation Plan, which symbolizes the PRC's unwavering commitment to the course of clean energy and energy efficiency investments in the BRI countries (Cuiyun and Chazhong 2020).

Kohl (2019) describes the BRI as an ambitious one seeking to establish modern trade routes, linking Eurasia and the Indian Ocean regions to the PRC. Kohl (2019) carried out a study on the BRI on supply-chain trade by considering 64 countries. The study concluded that infrastructure investments as a result of the BRI will yield asymmetric benefits to the PRC, the Russian Federation, and Southeast Asian countries as a result of greater access to the European markets.

The PRC seeks to use the BRI to provide the required assets needed to improve their economy through solidifying their global presence in the global value chain; these assets include labor and capital required for the construction of the requisite infrastructure, which includes high-speed railroads, ports, and oil and gas refineries (Chen 2018; Kohl 2019). Mainly, these are geared toward improving the smooth flow of goods. As much as there are multiple infrastructure development fronts associated with the BRI, some are likely to be used more to cut down delivery times. This is implied from the development of specific high-speed infrastructure such as high-speed railways. Typically a high-speed train's delivery time would be two times faster than a ship (Arduino 2016). According to Arduino (2016) in the BRI, railway access means that goods from the PRC can reach the EU market, and vice versa, faster than on container ships, which would take about 5 weeks, compared to 3 weeks on the railway system.

Ni (2015) indicated that the Yu'Xin'Ou Railway, which connects the PRC to Europe and cuts across six countries including Germany, has cut the time of delivery of goods by over 30 days compared to traditional shipping routes. According to Ni (2015) about 22% of the PRC's food imports come from Europe, and as the world's second-largest agricultural exporter, they are still seeking more opportunities in the PRC market. The PRC also seeks to gain from this relationship, as their agricultural produce's prices are largely higher than those of international standards (Ni 2015).

The timing of the BRI could not have been any better, especially for the European corridor. This is because it comes when several European multinationals are concerned about a reduction in the rate of global demand (Solmecke 2016). The BRI coincides with the period where EU member countries were struggling with investment. This, therefore, led to difficulties such as slow economic recovery that had adverse outcomes on jobs (Solmecke 2016). A 2015 European Union report on the European fund for strategic investments describes the situation as a crisis (European Union 2015).

8.3 Methodology

8.3.1 Design

The study used a quantitative method to examine GVC participation and some selected European countries' positions before and after the BRI declaration and commitment in 2015. It also aids in examining the impact of GVC participation on European countries' energy efficiency using a multiple linear regression model. To ensure that the right data are used the study used the survey design. The design helped in obtaining relevant and vital information that provided critical answers to the research questions.

8.3.2 Sampling Technique and the Data

The study used secondary sources of data from relevant databases. The data were obtained from the World Bank, the International Labour Organization, the International Monetary Fund, the UIBE, CODEX, and KNOEMA databases.

The GVC participation and position data were obtained from the World Bank, the International Labour Organization, the International Monetary Fund, and the UIBE website, while that of the energy efficiency index was obtained from CODEX. The study used panel data over a 7-year period from 2011 to 2017. The 2011 to 2014 period was classified as a period before the BRI, while the period 2015 to 2017 was classified as a period after the BRI. The reason is that most European countries committed to the BRI strategy was in March 2015. Moreover, the study used 36 European countries. In this research 1/(energy intensity) is a proxy for energy efficiency as in Bashir et al. (2020).

8.3.3 Variables Used

The variables used by the study are shown in Table 8.1.

Table 8.1 Introduction of the variables and the calculation meter

	Symbol	Variable	Explanation
Dependent variable	EE	Energy efficiency	1/(Energy Intensity)
Independent variables	GVCPINDEX	GVC participation index	Backward GVC participation (ratio of foreign value-added content of exports) to the economy's total gross exports Forward GVC participation (ratio of domestic value-added sent to third economies) to the economy's total gross exports
	GVCPOINDEX	GVC position index	Domestic value-added embodied in exports of final goods and services
	INVEST_ENE	Total investments (public and private) in the energy sector	Investment in the energy sector
	INVEST-RE	Private Investments in renewable energy	Private investments in renewables energy
	FOREIGN_EXCH	Foreign exchange reserves	Foreign Exchange reserves of European BRI countries
	TRADE_BALAN	Trade balance	Export–Import
	GDP	Gross domestic product	Gross domestic product in real terms

GVC global value chain. *Source* Authors' compilation.

8.4 Empirical Results

To determine the impact of GVC and investment in energy by private sector participation on EE deployments in European BRI countries, we developed a linear multiple regression model. In this model, the dependent variable is energy efficiency, and the explanatory variables are: GVC position index, GVC position participation, GDP, foreign exchange, trade balance, investment in renewables, and investment in energy.

For our regression, we used ordinary least squares (OLS). Table 8.2 shows the descriptive statistics of the data.

From the analysis, the results show that gvcpindex is significant in influencing the dependent variable EE investment in BRI countries, but has a negative relationship to EE. Raei et al. (2019) in their research suggested a direct relationship bewteen GVC participation and the infrastructure of a country. The negative signs indicate that BRI countries GVC participation will not contribute to improving energy efficiency but would rather worsen it. They should consider other ways to improve EE like investing in RES-E sources.

Further investigation, conducted by Wu et al. (2020), indicated that participating in GVC has no direct relationship with renewable energy consumption except for the Middle East and North Africa and the Sub-Saharan African regions. However, gvcpoindex is not significant in determining the relationship between the EE investment in BRI countries. Another striking significance is that GDP growth, while not substantial, has a negative association as well. This is striking because these are emerging countries with booming economies and hence should have higher GDP growth rates.

Table 8.2 Linear regression results

	Coef.	St. Err.	t-value	p-value	Sig
GVCPINDEX	−7.024	1.559	−4.51	0.000	***
GVCPOINDEX	4.812	3.750	1.28	0.201	
GDP	−0.042	0.045	−0.94	0.350	
FOREIGN_EXCH	0.000	0.000	−0.47	0.639	
TRADE_BALAN	0.000	0.000	3.90	0.000	***
INVEST_ENE	0.040	0.006	6.35	0.000	***
INVEST-RE	0.051	0.049	1.04	0.298	
CONSTANT	4.279	0.421	10.18	0.000	***

Note ***$p < 0.01$
Source Authors' calculation

Furthermore, foreign exchange was not significant. Another significant variable was the trade balance, which has a direct correlation with EE investment. Also, investment in energy in private sector participation is equally significant, as was anticipated before the analysis. The relationship explains that as an investment in energy with private sector participation increases, EE investment would increase. This is supported by Mohsin et al. (2020) who revealed the need for developing countries to formulate policies to scale-up renewables energy investment. A variable that proved insignificant was renewable energy, which was not anticipated.

8.4.1 Level of GVC Participation Before and After the BRI

To understand the status of the BRI effects on European countries' GVC participation, the study sought to determine the level of GVC participation before and after the implementation of the BRI (in 2013) in European countries. The result is presented in Fig. 8.1.

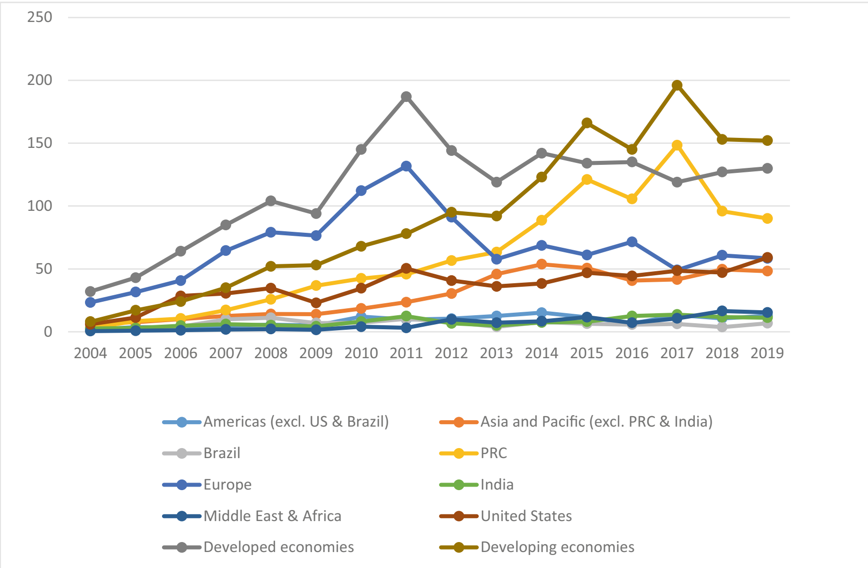

Fig. 8.1 Global trends in renewable energy investment ($ billion). *PRC* = People's Republic of China, *US* = United States. *Source* Authors' calculation based on International Renewable Energy Agency (IRENA)

Investment in alternative energy technologies is on the rise globally. Figure 8.1 shows global trends in renewable energy. It indicates that developing economies invested a significant amount of money in renewables in 2017 and 2018, followed by developed economies. It is noted that all the regions experienced an increase from the investment levels since 2010 and kept on a steady growth path and slowed along the path, and increased again around 2013 and has been on a growth trajectory. Europe and the United States have invested heavily in the renewables, followed by the PRC, Sub-Saharan Africa, and the Middle East. North Africa invested the least in the renewables sector. The developed countries, especially Europe, have invested heavily and are commanding the lead regarding achieving the SDGs. The case of Sub-Saharan Africa is evidenced by the fact that the continent installed only 2% of renewables investments. Africa needs to increase its investments in the energy sector to create energy access and eliminate energy poverty. More than two-thirds of the people without access to electricity live in Sub-Saharan Africa (Bellon et al. 2020; Alemzero et al. 2020).Thus, the BRI is a laudable project in helping Africa meet this energy need.

Figure 8.2 shows the results of the GVC participation index of 36 selected European countries. The results show an improved and balanced GVC participation of most European countries from 2011 to 2017. The results show how these 36 European countries participated in GVCs before the adherence to the BRI strategy in 2015 by most European countries and after the strategy consideration after 2015. The results show an even GVC participation by most European countries, including Denmark, Lithuania, Latvia, Poland, Italy, United Kingdom, Germany, Austria, Portugal, Bulgaria, Cyprus, Czech Republic, France, Estonia, Hungary, Slovak Republic, and Slovenia, among others. Luxembourg, followed by Ireland and the Netherlands have the most dominant GVC participation of the 36 European countries. The lowest representations are Ukraine, Moldova, Belarus, Albania, and Bosnia & Herzegovina. It is clear from the results that most European countries' dominant powers do not show a greater GVC participation index compared to those who are less powerful countries in Europe. Despite this, the findings across the countries indicate that GVCs participation is undulating across the sampled years from 2011 to 2017. The findings show significant improvement in trade openness of most European countries across the globe. This projects that most European countries, especially Luxembourg, Ireland, Netherlands, the United Kingdom, and others, have a greater value-added in relation to their gross exports and inputs value. It is also vital that understanding most European countries excluding Ukraine, Moldova, Belarus, Albania, and Bosnia & Herzegovina have observed enhanced foreign exchange, greater trading, and greater investment. This explains the critical and significant even distribution of GVC participation index of most of the 36 countries.

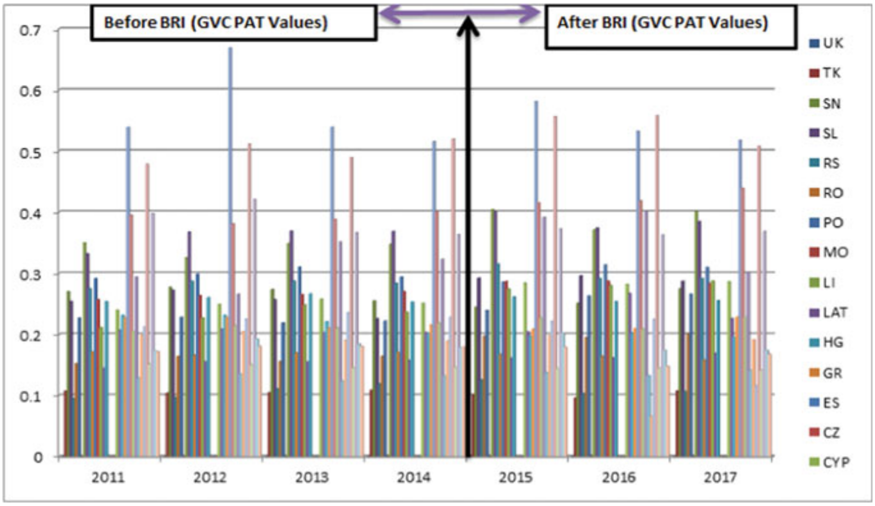

Fig. 8.2 GVC participation before and after BRI. *BRI* Belt and Road Initiative, *GVC* global value chain, *PAT* participation. *Source* Authors' calculations

Figure 8.2 shows the results from examining the GVC participation before the BRI (2011 to 2014) and GVC participation after March 2015 to 2017. The results show significant improvement in GVC participation of 36 European countries from 2011 through to 2014 (before the BRI) with the worst participation index observed in 2011. However, after the BRI is observed in the GVC participation values, it is clear that there is a slight improvement of participation of European countries in the GVC from 2015 to 2017 compared to 2011 to 2014. This can be attributed to opening up to the BRI strategy. This indication shows significant trade opening in terms of GVC of most of the 36 European countries in recent years compared to previous years. This suggests that the significant improvement of European countries' participation index regarding GVC can be attributed to the action of expanding their economies through global trading, investment, leading to more remarkable improvement in their overall growth in foreign exchange, trade, exports, and inputs, especially after 2015. This means that most countries perceive Europe as a vital area of world connectivity through the BRI, resulting in policy liberalization. This also implies that with the global trading business, a greater share of GDP of most countries are traded with the PRC through the connectivity, making Europe a vital investment area of global business connectivity.

Table 8.3 GVC participation index (%)

Countries	2011	2012	2013	2014	2015	2016	2017
	%	%	%	%	%	%	%
Ukraine	0	0	0	0	0	0	0
Turkey	10.74	10.41	10.46	10.87	10.13	9.62	10.76
Slovenia	27.02	27.74	27.37	25.49	24	25.13	27.48
Slovak Republic	25.38	27.21	25.69	22.62	29.26	29.59	28.69
Russian Federation	9.52	9.65	11.08	11.87	12.61	10.37	10.65
Romania	15.24	16.41	15.59	16.46	19.69	19.51	20.09
Poland	22.70	22.81	21.88	22.21	23.92	26.32	26.61
Moldova	0	0	0	0	0	0	0
Lithuania	34.89	32.48	34.79	34.68	40.39	37.06	40.11
Latvia	33.12	36.71	36.88	36.81	40.05	37.39	38.45
Hungary	27.466	28.72	28.73	28.39	31.56	29.15	29.18
Greece	17.09	16.59	16.97	17.08	16.72	16.44	15.87
Estonia	29.15	29.87	31.02	29.43	28.62	31.41	31.01
Czech Republic	25.68	26.35	26.51	27.02	28.69	28.78	28.34
Cyprus	21.11	22.72	24.82	23.69	27.42	28.03	28.78
Croatia	14.49	15.54	15.52	15.77	16.12	16.15	16.90
Bulgaria	25.41	26.07	26.69	25.29	26.19	25.39	25.54
Bosnia and Herzegovina	0	0	0	0	0	0	0
Belarus	0	0	0	0	0	0	0
Albania	0	0	0	0	0	0	0
Austria	23.99	24.95	25.81	25.12	28.43	28.19	28.67
Switzerland	20.71	20.88	20.34	20.30	20.42	26.71	22.59
United Kingdom	23.16	23.17	22.08	20.17	19.73	20.25	19.58
Portugal	22.75	22.76	21.11	21.53	20.86	20.95	22.80
Luxembourg	53.90	66.91	53.89	51.54	58.09	53.25	51.76
Belgium	39.45	38.02	38.81	40.06	41.53	41.86	43.88
Germany	20.52	21.43	21.01	21.92	22.75	20.94	22.81
Denmark	29.42	26.61	35.05	32.19	39.09	40.14	30.18
Spain	12.84	13.52	12.40	13.21	13.75	13.25	14.09
Finland	19.91	20.48	19.07	18.94	19.83	6.61	19.09
France	21.23	22.52	23.57	22.83	22.13	22.53	11.57
Ireland	47.87	51.13	48.92	51.97	55.60	55.75	50.79
Italy	15.12	15.02	14.57	14.62	14.42	14.46	14.11
Netherland	39.79	42.06	36.61	36.32	37.22	36.24	36.81
Norway	17.28	19.25	18.46	17.89	20.23	17.37	17.39
Sweden	17.19	18.06	18.06	17.96	17.88	14.77	16.75

GVC global value chain. *Source* Authors' calculations

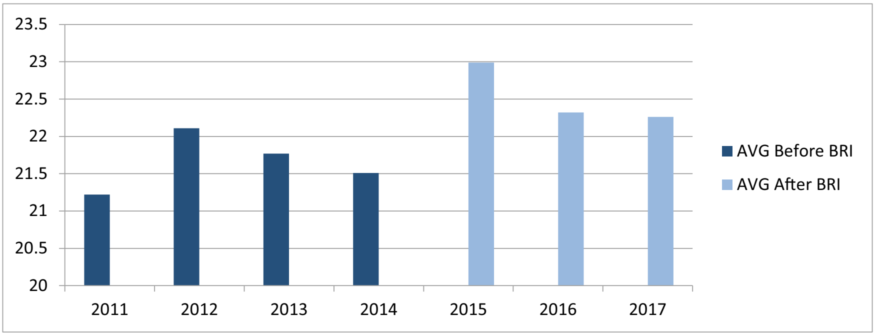

Fig. 8.3 Average GVC participation of European countries, 2011 to 2017. *AVG* average, *BRI* Belt and Road Initiative, *GVC* global value chain. *Source* Authors' calculation

The results of the GVC participation index expressed as a percentage across countries are presented in Table 8.3. The results show zero GVC participation for Ukraine. Similarly, with regards to Turkey, the highest GVC participation was recorded in 2014 at 10.87%, followed by 2017 at 10.76%, and the lowest value in 2016 thus 9.6%. With Slovenia in 2017 recording the highest GVC participation index of 27.48%, followed by 2012 which is 27.74% and the least value was 24.49%. Moreover, Slovak Republic had 2016 as its best record of GVC participation index of 29.59% and the lowest value in 2014 recording 22.62%. In addition, the Russian Federation recorded 12.61% in 2015 being the highest with the lowest record in 2011 which is 9.52%. Poland, Latvia, Hungary, Austria, Portugal, Germany, Spain, among others, recorded their highest values in 2017 of 26.61%, 29.18%, 28.67%, 22.80%, 22.81% and 14.09%, respectively. Similarly, most European countries observed the greatest record of their GVC participation between 2015 through to 2017, with few countries observing the highest values of GVC participation before 2015. This shows significant improvement of GVC participation of majority European countries across the globe. Although, some countries observed a steadily decline in their GVC participation especially the United Kingdom and Luxembourg across the years, the general GVC participation trend for most of the countries were positive with few undulating trends. With these indices, it is clear that a number of the countries after 2015, perceive Europe as key to global connectivity through the BRI resulting in policy liberalization strategies.

The results presented in Fig. 8.3 show the average GVC participation of European countries from 2011 to 2017. The results show that with regards to the 36 European countries, the most outstanding year for improved GVC participation index was 2015, followed by 2016 and 2017 which are after the implementation of the BRI; while the lowest representation was in 2011. It is clear that before the BRI, the GVC participation average values in 2011, 2012, 2013, and 2014. The discovery significantly projects that the open trade business of most European countries was realized after the BRI strategy adherence and commitment decision was announced by most of these countries. To a large extent the aim of the BRI stressed here as a project that provides the required assets needed in the GVC to improve economies; these assets include labor and capital required for the construction of the requisite infrastructure, which includes high-speed railroads, harbors, and oil and gas (Chen 2018; Kohl 2019). An important project carried out by the BRI can also be indicated to be at play at this point.

8.4.2 *Determining the Level of GVC Position After BRI*

The study's second objective was to determine the GVC position of European countries before and after the BRI commitment proclamation. This is aimed at establishing the position of European countries within the GVC space across the globe. The relative position of European countries on GVC provides a clear indication of their trade relationship and sectoral businesses in other regions. Although, the objective does not cover sectoral analysis of the GVCs of these countries, it provides an overall relative position of 36 selected European countries. The position provides a great level of understanding in light of trade policy requirements of these countries in recent times. It also indicates the new paradigm shift of these countries in terms of their trading before and after the BRI strategy commitment decisions. The result of the GVC position index of the selected countries is presented in Fig. 8.4.

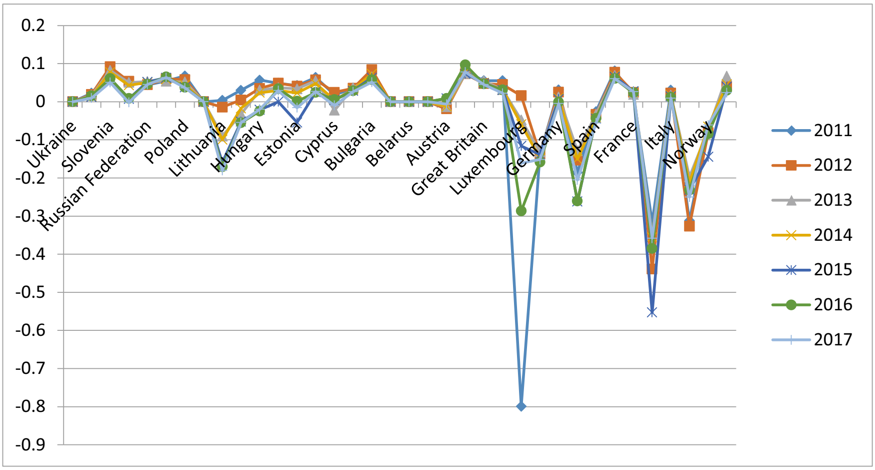

Fig. 8.4 GVC position index of European countries. *GVC* global value chain. *Source* Authors' calculations

Figure 8.4 shows the GVC position of selected European countries. The position index in the GVCs is effectively projected in two streams: upstream and downstream levels. The primary inputs requirement is dependent on the upstream trade arrangement whilst that of the downstream covers production and general trading and consumption. The result shows negative and positive position indices of the GVCs of the selected European countries. However, most of the countries observed negative position indices. The countries within this position index level include Germany, Spain, Italy, Norway, among others. The indication is that most of the great powerhouses of Europe recorded negative GVC index across the sampled years. This shows that most dominant powers countries in Europe do not show a greater GVC position index. The results also show that the less powerful countries in Europe have greater positioning within the positive indexing including Bulgaria, Slovenia etc. The findings also project that most of the European powerhouses' GVC positioning is within the upstream area. This means most of the concentration of European countries is within the primary inputs trading with minimal levels operating in the downstream trading. This to a large extent can result from these countries trying to maximize the benefit associated with operating in the upstream section. As indicated by the OECD markets (2013) the highest level of value creation in a GVC is usually located in upstream activities, which includes developing a new concept or the manufacturing of important parts.

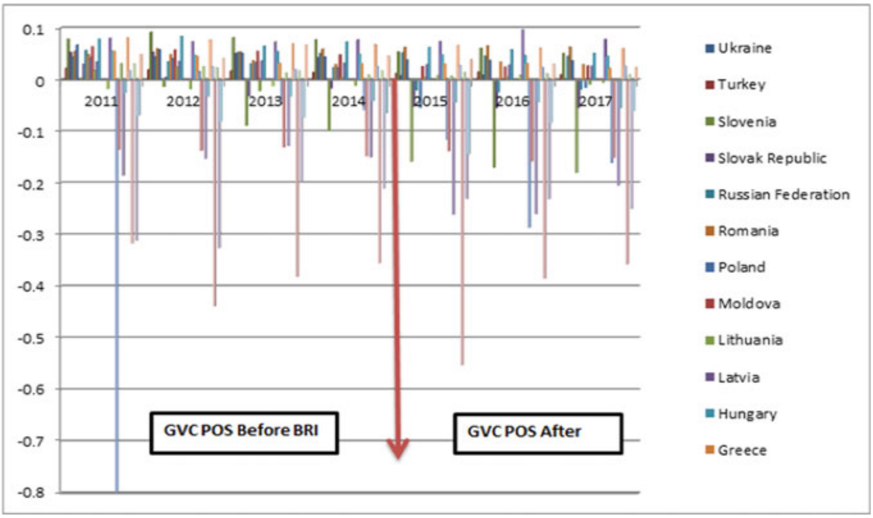

Fig. 8.5 GVC position across years (before and after the BRI). *BRI* Belt and Road Initiative, *GVC* global value chain, *POS* position. *Source* Authors' calculations

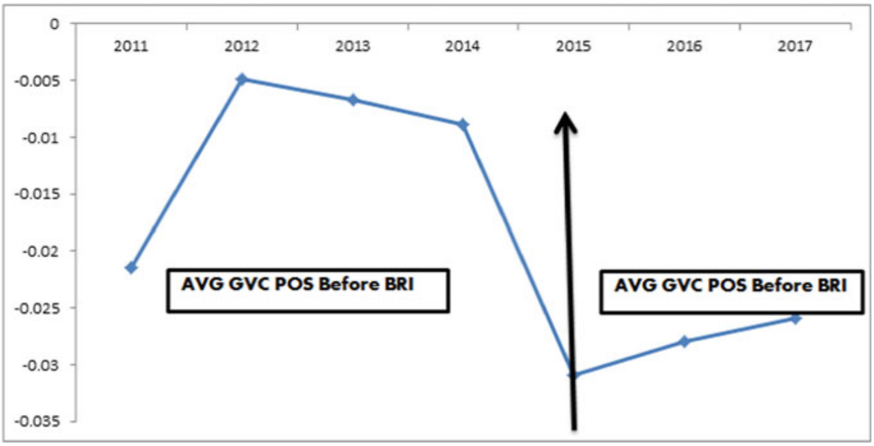

Fig. 8.6 Average GVC position in years. *AVG* average, *BRI* Belt and Road Initiative, *GVC* global value chain, *POS* position. *Source* Authors' illustration

The results presented in Fig. 8.5 show the GVC position of European countries from 2011 to 2017. The result was presented in two components: GVC position before the BRI (2011 to 2014) and GVC position after the BRI (from March 2015 to 2017). The position trend result shows significant negative positions or decline in the position across the years. The result shows general negative or decline in the position of the countries from 2011 through to 2017, however, with significant decline in 2011. Although, the general GVC positions of the countries are relatively negative both before and after the BRI, it shows the level of GVC participation of most of these countries. This form of positioning across the years can be attributed to the initial doubt regarding European countries involvement in the BRI strategy leading to the delay in the BRI commitment by these countries.

The results presented in Fig. 8.6 show the average GVC position of European countries across the years. The results generally show an abysmal GVC position of European countries across the years. On average, the results succinctly show that with regards to the 36 European countries, the most outstanding year for improved GVC position index is 2012, followed by 2013, and the least represented in 2015. It is also clear that before the BRI, GVC position average values were better than after BRI strategy commitment by European countries. Although the participation values indicate that the open trade business of most European countries was realized after the BRI strategy adherence and commitment decision, this is not seen in the GVC positioning of these countries.

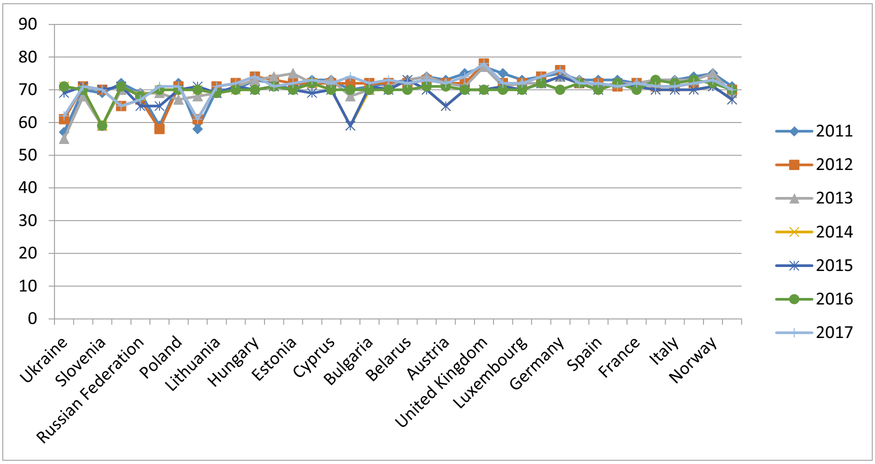

Fig. 8.7 Energy efficiency movements in European countries. *Note* Energy efficiency in this research is calculated by (1/energy intensity). *Source* Authors' calculations

8.4.3 *Impact of GVC Participation Before and After the BRI on Energy Efficiency Investment*

The study employed the energy efficiency index from CODEX data to examine how GVC participation before and after the BRI exerts effect on energy efficiency investment. Energy efficiency means using less or minimal level of energy to perform the same task (EESI 2019). This process helps to eliminate energy waste in the system. Through this, variety of benefits are obtained from effective energy efficiency investment including the reduction of greenhouse gas emissions, the reduction in demand for energy imports, and the lowering of costs on households and the economy-wide level (EESI 2019; Shove 2017). In light of this, the energy index values were calculated using data energy efficiency data obtained from CODEX. The result is presented in Fig. 8.7.

Figure 8.7 shows the energy efficiency index of the selected 36 European countries. It showed an improved energy efficiency investment for most of the countries across the selected years. The improve rate on average is 1.4 years across most of countries. The general improvement is between 10 to 30% on average from 2011 through to 2017 for most of the countries. The results show that the most improved countries with regards to energy efficiency are Turkey, Slovenia, Romania, Poland, Lithuania, Croatia, Cyprus, Austria, and Sweden. It is clear that the most dominant power house of Europe has average improvement in energy efficiency index. This shows that most of the countries in Europe use less energy in performing the same task as in previous years.

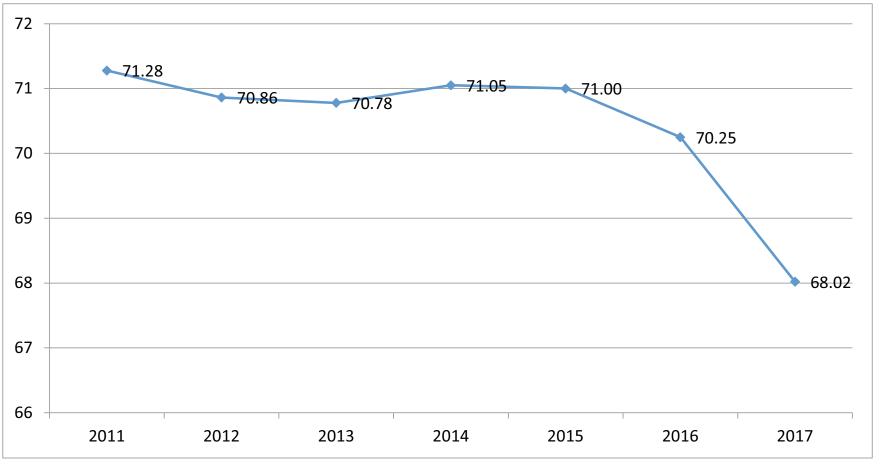

Fig. 8.8 Average values of energy efficiency, 2011 to 2017. *Note* Energy efficiency in this research is calculated by (1/energy intensity). *Source* Authors' calculations

Table 8.4 Impact of GVC participation on energy efficiency (using BRI strategy)

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	Beta		
1 (Constant)	485.539	5.371		90.392	0.000
GVC Participation Before BRI	24.608	29.357	0.752	0.838	0.408
GVC Participation After BRI	18.543	36.636	0.454	0.506	0.116

Note Dependent Variable: Energy Efficiency (1/energy intensity). *BRI* Belt and Road Initiative, *GVC* global value chain. *Source* Authors' calculations

Figure 8.8 shows the results of the average energy efficiency index of 36 European countries across the years under review. The results show an improved energy efficiency from 2011 through to 2017. It is clear that as the years go by European countries see improvement in their energy efficiency index. The figure shows a general decline of the EE values from 2011 through to 2017. This shows that most European countries are more energy efficient thus in 2015 through to 2017 as compared to 2011 through to 2014. This indicates a greater improvement in the general energy efficiency investment of European countries.

Further, the study evaluated whether there has been a significant impact on the energy efficiency of European countries after BRI, the results of this are presented in Table 8.4.

The regression result presented in Table 8.4 shows no statistically significant prediction of the GVC participation on energy efficiency both before and after the BRI as p value was greater than 0.05.

Generally, the impact result shows no effect of the BRI strategy on energy efficiency investment issues of European countries, although the overall GVC participation did. The trend discoveries show that from 2011 through to 2014 energy efficiency improved by 1.2% per year whilst 1.4% was achieved from 2015 through to 2017 each year. Culminating with the impact effect, this shows that GVC participation is important with regards to the energy efficiency investment issues within Europe. Energy efficiency across sectors and households in Europe has increased tremendously from 2011 through to 2017. Although, there were average steadily slowdown in energy efficiency issues for most of the countries, improvement became high after 2014. Although the general consumption rate has reduced across the years, tremendous improvement has been recorded on the efficient use of energy across the utilized years.

8.5 Conclusions and Policy Recommendations

GVCs have come to stay in the current era of international trade. Generally, it makes sense to operate in a system that promotes the transfer of knowledge, the advancement of technology, and the creation of a wide range of employment. Generally, all these are pushed by trade liberalization across borders. Ideally, any program or initiative that seeks to promote GVCs such as the BRI is assumed to result in the positives that are associated with global trade improvement. However, this assumption needs to be proven, which emphasizes the need to study the BRI extensively.

One interesting note about the BRI is its nature, which is more altruistic in its outlook. Of course, there are some doubts about this claim, but currently, being an initiative that is still in its pioneering stage, it is difficult to paint a full picture of the influence of the initiative. Regardless, this study has been able to establish some interesting findings.

From the study, it is clear that there were both negative and positive position indices of the GVC positions of the selected European countries. Most of these countries though observed negative position indices. It is difficult to establish why this as the study is limited to only establishing the GVC position with the BRI in the picture. However, it can be assumed that the dominant-negative positions can be as a result of the initiative still being in its early stages; considering that several European countries were slow to adopt the project, even though it came at a point when a number of the European countries were desperate for more foreign investment to boost their economies. The doubts about the real aim of the intuitive obviously make up for part of the restraining factors. This goes to imply that a longitudinal factor, at least one that evaluates the initiative’s long-term effect as the year goes by is one that is encouraged.

An important factor of GVC also showed interesting results. Energy efficiency has been established to be a key concern of most GVC players. There have been growing concerns for the need to use fewer resources and conserve energy that yields effective results. The study established that indeed before and after the BRI there has been an increase in energy efficiency investment over the years. It was also clear that European countries' GVC participation has a significant link with the energy efficiency investment of these countries. This implies that these countries' GVC participation has made it possible for knowledge and technology to be shared to improve energy efficiency investment.

However, looking at the different eras, before and after the BRI, the result showed that there is no statistically significant prediction of the GVC participation on energy efficiency investment even though to a large extent there have been improvements after the BRI. It can be implied that the insignificant link is as a result of the program being in its early stages, hence the full effect might be assumed to be immature. To a large extent, future studies on this phenomenon which should center on a more longitudinal approach is encouraged and also factoring countries from other regions would be instrumental in furthering the understanding of the topic. Based on the above, the following recommendations were arrived at.

First, the BRI countries should formulate, institute, and implement robust renewable energy regulatory policy instruments such as feed-in tariffs, taxes, and subsidies, to de-risk investments in the renewables sector. This will attract investors and help in scaling-up the deployment of RES-E resources. These policy instruments guarantee markets for investors.

Second, leveraging green finance is crucial. Green finance will channel investment to clean energy technologies and limit polluting and high-intensive investments like renewable energy covered bonds (green bonds). The BRI countries need to implement financial innovation by coupling green finance to these national strategies and policies.

Third, BRI countries should take steps to avoid a carbon lock-in situation, deciding to diversify their energy mix. The BRI energy projects include building fossil fuel plants and coal plants in member countries.

Fourth, an assessment of integrated resource planning is key in the power sector, in order to couple renewables and energy efficiency. This will inject flexibility into the system on both demand and supply sides and a low carbon sector.

Fifth, international cooperation is needed by the BRI countries to benchmark international best practices regarding building resilient infrastructure and developing countries' risk reduction strategies.

Sixth, the BRI countries should adopt a blended finance policy instrument to complement any other financing sources. Blended finance solutions will assist in catalyzing investments from all angles to speed up the development of green projects.

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Conflict of Interest The authors declare no conflict of interest.

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Part III
Country Case Studies

Chapter 9
District Heating Business Models and Policy Solutions: Financing Utilization of Low-Grade Industrial Excess Heat in the People's Republic of China

Yang Liu, Shan Hu, Brian Dean, and Xilong Yao

Abstract The People's Republic of China (PRC) has taken bold actions to utilize low-grade industrial excess heat to improve energy efficiency of districting heating systems since 2016. This study aims to draw policy insights into the PRC's field experience with overcoming barriers to energy efficiency financing. First, we investigate split incentives, third-party access, and lack of heat resource mapping as key barriers of investing in district heating energy efficiency projects. Second, to enable the energy efficiency financing market, we analyze three business models: a utility-led model with third-party access, a heat production competition model, and an energy service company integrated model. The decision making in choosing these options in large part depends on the integration level of production, transmission, and distribution activities in a given district heating system. Third, the heat prices must signal new investments in district heating capacity adequacy. We suggest four options of excess heat pricing system cost, free-cost, a quantity target for clean heating, and indexing against the next best alternative. Finally, we conclude with policy implications to scale up energy efficiency financing in district heating. Although the analysis is specific for the PRC, the policy and financing issues are global opportunities for improving energy efficiency in district energy systems.

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Keywords Energy efficiency · District energy system · District heating · Excess heat

JEL Classification Q48 · H32

9.1 Introduction

Energy efficiency is a key national strategy for sustainable development in the People's Republic of China (PRC). In the 13th five-year plan (2016–2020), the country aims to reduce energy intensity per unit of gross domestic product (GDP) by 15% in 2020 compared to 2015. If the PRC's GDP grows by 6.5% annually over 2016–2020, this target implies increasing energy savings by 16% compared to 12th five-year plan, equivalent to absolute energy savings of 23 exajoules (EJ) (780 metric tons of carbon equivalent [Mtce]).

As a primary measure of improving energy efficiency, the government plans to promote the utilization of low-grade excess heat in district heating systems, with a target of replacing more than 1.5 EJ (50 Mtce) coal-based heat production associated with the heating area of more than 2 billion square meters (m^2) of buildings by 2020. This plan also aims to pilot clean heating projects in 150 cities. At the Group of 20 (G20) Energy Ministerial held in 2016, the newly endorsed G20 Energy Efficiency Leading Programme (EELP) highlighted district energy systems as a key area of future collaboration. In 2018, the China National Development and Reform Commission published the Clean Heating Plan of Northern Region (2017–2020), as a guideline to promote clean heating in the PRC.

With the largest district heating system in the world, the heating area increased, from 5 billion m^2 to 14.7 billion m^2 between 2001 and 2018, due to the improved living standards and population growth. The annual energy consumption for space heating reached 6.2 EJ (212 Mtce) in 2018, representing about 21% of the total energy consumption in the PRC's building sector (TU 2020).

The energy intensity of the heating services in the PRC, expressed as the ratio of heating energy consumption and heated floor area, decreased by 37% from 0.67 gigajoules (GJ)/m^2 in 2001 to 0.42 GJ/m^2 in 2018. The replacement of small heat-only boilers with centralized combined heat and power (CHP) sources and wide-spread adoption of energy efficiency measures in the building sector, explains some of the improvement in the space heating energy intensity (IEA and TU 2015).

Heating services in the PRC rely heavily on coal. More than 90% of the building floor area is heated by coal cogeneration (combined heat and power) and/or coal boilers. The capacity of the natural gas boilers has increased to 8% of the total heating floor area. However, the relatively high cost of natural gas compared to coal makes the district heating less affordable without government subsidies.

More than ever, the challenges of controlling air pollution and capping coal consumption have prompted the PRC to develop clean alternatives to its coal dominant district heating system. For this, the government engages a series of actions by recovering excess heat to enhance energy efficiency of district heating systems.

The use of excess heat and pressure is a major country-wide energy-saving measure (State Council 2016). Financial support policies, in the forms of investment subsidy and preferential tax treatment have been provided over the period of 11th and 12th five-year plans (2006–2015). Most commercially viable heat recovery projects have already been implemented. Indeed in the PRC, about 55% of excess heat potential, mainly high and medium grade excess heat has already been recycled for energy generation or onsite industrial processes (IEA and TU 2015). However, low-grade industrial excess heat, usually defined as flue gas below 200 °C or liquid below 100 °C, is rarely recycled for energy use.

While it is well known that the PRC has the world's largest manufacturing sector, which produces a huge amount of industrial low-grade excess heat, the literature on this regard remains limited. Fang et al. (2013) and Fang, Xia, and Jiang (2015) conclude that recovering low-grade industrial excess heat for low-temperature district heating can provide multiple benefits for factories, heat-supply companies and society in the PRC. Li et al. (2016) study technological options and provide a cost–benefit analysis for the collection and delivery of industrial excess heat in the northern PRC. Likewise, based on the cases in Denmark, EUDP (2014) investigates efficiency benefits of district heating networks through increased utilization of renewable energy and low temperature resources. Meanwhile, various barriers exist to prevent effective consideration of low-grade industrial excess heat for district heating purpose. Söderholm and Wårell (2011) highlight third-party access as the key barrier to introducing clean heat sources into district heating. ESMAP (2008) suggests that the PRC might need to implement market-based pricing and consumption-based billing to commoditize heat supply and thus incentivize efficiency improvement. Liu et al. (2019) quantify the gap of energy efficiency improvement attributed to the information asymmetry between the government and industries in the PRC. This study aims to fill the knowledge gap through a comprehensive analysis of financing models and pricing schemes applicable to utilization of low-grade industrial excess heat in district heating systems.

The remainder of this chapter is organized as follows. Section 9.2 describes opportunities and challenges of scaling up the integration of low-grade industrial excess heat into the district heating system. Section 9.3 investigates three business models for financing district heating energy efficiency projects. Section 9.4 examines four options related to excess heat pricing. Section 9.5 conclude with a range of policy options to enable energy efficiency financing.

9.2 Opportunities and Challenges in the PRC's District Heating Market

9.2.1 The PRC's Low-Grade Excess Heat Potential

Tsinghua University (TU 2018) investigates the technical potential for recovering and using low-grade excess heat from major industries in northern PRC. The analysis concludes that there is a huge untapped potential of 3 EJ (100 Mtce) for industrial excess heat that can be used in the district-heating networks. This amounts to roughly half of the current energy demand for district heating in northern PRC (TU 2018). In many cities such as Shijiazhuang, Tangshan, Handan, Qinhuangdao, and Chengde, the quantity of excess heat can meet a significant part of heat demand. Tangshan has seen the amount of excess heat even surpass its heat demand. It is noted that in all these cities, a major part of the excess heat is characterized by a temperature lower than 50 °C.

Specifically, energy-intensive industries are geographically concentrated in a few provinces such as Hebei, Shandong, Jiangsu, Liaoning, Shanxi, Henan, and Heilongjiang. Among these areas, Hebei is the largest industrial province surrounding Beijing and Tianjin (Li et al. 2016; NDRC 2017). Beijing, Tianjin, and Hebei are collectively known as Jingjinji, a name derived from the acronyms of all three areas. Jingjinji region is not only the political center of the PRC but also one of the heavy industry bases. Specifically, Hebei represents 25% of national steel production, and more than 5% of national cement production. Over recent years, Jingjinji has been suffering from heavy smog, especially in the winter season, which is in large part attributed to fossil-fuel consumption for the supply of district heating (Clean Air Asia 2015).

TU (2018) suggests that the PRC should consider connecting district energy systems of neighboring cities to solve the shortage in clean heat sources and severe air pollution, primarily in Jingjinji. For example, large-diameter water tubes and networks could be established to link Beijing, Tianjin, Tangshan, and other cities. In this way, the main district heating facilities, including CHP plants, heat-only boilers, and industrial excess heat resources, could be integrated into an overall system. Thanks to smart heating technologies, heat-rich cities could provide surplus heat to heat-poor cities. This will help replace coal consumption and balance heat demand and supply across regional borders.

9.2.2 Characteristics of District Heating Systems

Industrial excess heat is usually heterogeneous, dispersed, and intermittent. These characteristics mean that, to make industrial excess heat as part of the baseload in a district heating system, the operator will need to maintain back-up heating capacities. Significant balancing costs are required to adjust and integrate various temperatures grades of heat sources in district heating systems. It is therefore essential to having a complete understanding of various costs associated with utilization of industrial excess heat. In fact, this entails a rethink of our district energy system from both technological and investment perspectives (et al. 2020).

The value chain of district heating services involves a series of generating, integrating, adjusting, transporting, distributing and consuming processes. Understanding the heat market as a system (Fig. 9.1) from production to distribution and from the system planning to monitoring can enable finding energy efficiency opportunities. System-based screenings of technical and economic assessments usually lay the basis for the most cost-effective way to utilize excess heat in district energy systems. In many cases these assessments also contribute to developing sound policies to support the long-term transformation of the whole energy system. For example, the European Union's Energy Efficiency Directive endorsed in 2014 has made it compulsory to use industrial excess heat for district heating when the payback period of investments is less than 4 years.

From the technical point of view, in order to improve the energy efficiency of the district heating system, it is important to ensure that the return and supply temperatures are as low as possible, meanwhile keeping the difference between the supply and return temperature (cooling) as large as possible (Söderholm and Wårell 2011). Changes in energy mix may have a large impact on district heating networks operations. Various components of district heating networks are highly interdependent, both at a plant level and as a system. An important feature of the district heating is its operational inter-linkage between production, distribution, and consumption activities. For example, the level of the supply and return water temperatures can affect the heat and electricity output. Maintaining low temperatures can provide several benefits in a district heating system, such as increased

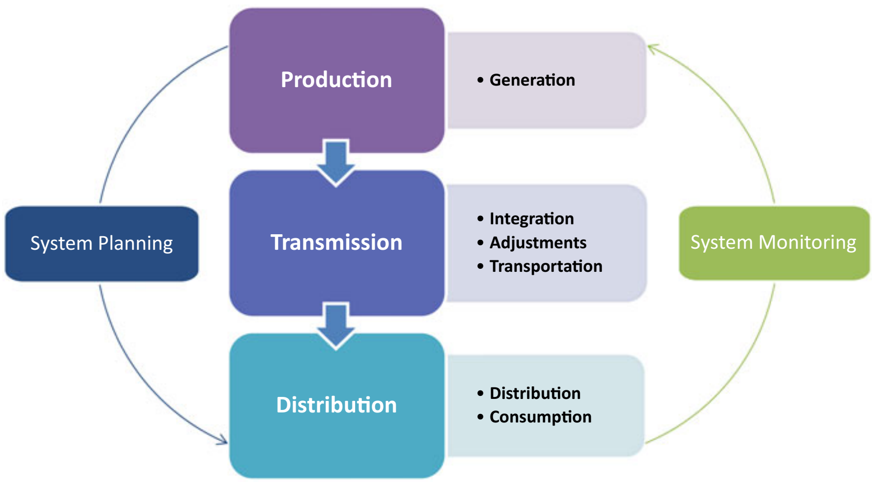

Fig. 9.1 Heat market as a system with key components. *Source* Authors' own elaboration

electricity output from CHP plants, improved capacity of heat recovery from industrial excess heat, an increased coefficient of performance for heat pumps, and reduced distribution losses (EUDP 2014). Therefore, economic performance across the entire district heating system can vary greatly with the control of water temperatures.

More importantly, utilization of excess heat from industrial sites in local district heating networks is one of technologies that can contribute to improving the flexibility of the whole energy system (Fig. 9.2). In an energy environment of increased complexity, flexible technologies are highly valued: technologies that can rapidly adapt to operating loads, absorb or release energy when needed, or convert a specific final energy into another form of energy are increasingly important in energy systems (IEA 2016a).

Increasing integration of fluctuating energy sources such as renewables from solar and wind requires enhancing flexibility of the electricity grid. The power system currently heavily relies on large-scale CHP plants in the northern PRC. The flexibility of the power dispatch system is constrained in the winter season since these CHP plants must be run to ensure heat supply as a social welfare. This leads to significant curtailment of wind generated electricity. One option to provide this much needed flexibility is to use low grade industrial excess heat to reduce the reliance on CHP plants.

Nevertheless, mainstreaming heat planning into a broader energy policy framework is challenging. In the PRC, cities are responsible for developing their own heat policies, and the implementation of heat planning reforms depends, in large part, on a local government agenda. Meanwhile, the electricity utilities are

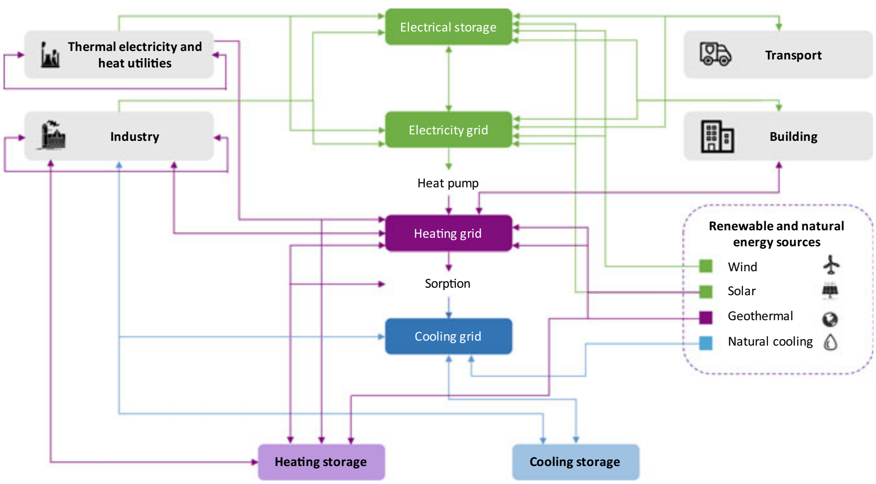

Fig. 9.2 Interconnections of electricity and thermal energy in an integrated energy system. *Source* IEA (2014)

mainly owned by the central government and national champions. Therefore, integrating heat and electricity markets requires a holistic approach.

9.2.3 Challenges in the District Heating Market

In this section, we investigate three key challenges of investing in energy efficiency projects in district heating systems. These barriers include (i) split incentives between production, transmission and distribution activities, (ii) third-party access to the heat network, and (iii) heat mapping in the energy system planning (Fig. 9.3).

Split Incentives
Split incentives can occur across several business relationships, when entities capable of making improvements have split off payoffs and risks and the entity benefiting from the improvement has no ownership over the long-term savings. Indeed, multiple split incentives exist at both supply and demand sides of district heating systems that prevent the scale-up of energy efficiency investments (Liu, Yao, and Wei 2019; Hu et al. 2017).

Split Incentives Between Heat End Users and Producers
The PRC's heat market has been reformed to some extent with consumption-based billing. However, commoditizing heat is not yet fully adopted by the market players and consumers. Heat billing is largely based on a flat energy cost per square meter regardless of the amount of energy consumed or level of comfort. Many employers pay the heat bills for their employees, as part of the social welfare system

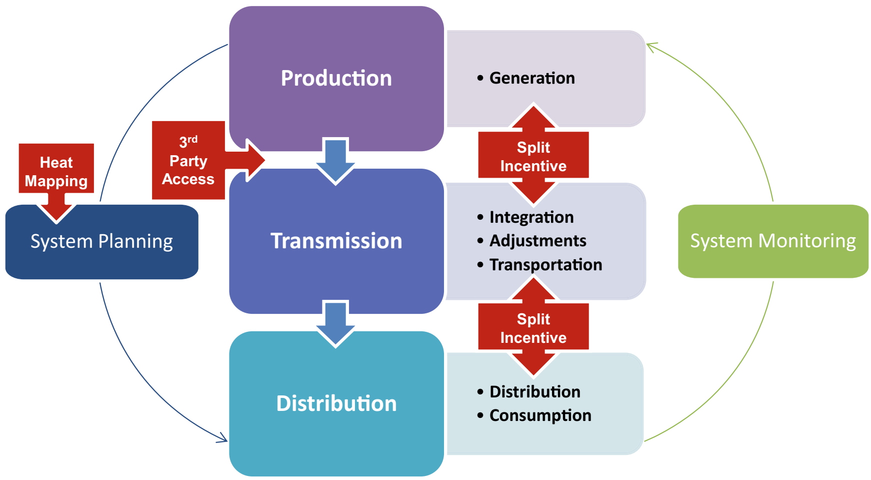

Fig. 9.3 Key barriers of energy efficiency for district heating systems. *Source* Authors' own elaboration

(World Bank 2009). Heat tariffs are highly regulated to allow low-income consumers to access heating services, but result in heating companies claiming that the current level of heating revenue is not able to sustain and improve the heating services.

The Ministry of Housing and Urban–Rural Development estimated that the consumption-based billing area was 805 million m^2 in 2013, representing about 7% of the total building stock. The World Bank launched an 8-year implementation program in 2003. However, the project fell short of its targets for promoting billing based on heat consumption across the country (World Bank and ESMAP 2012). This partially reflects the complexity of commoditizing heat in the country's social and economic contexts.

It is well known that lower system temperatures in district heating systems will lead to saving primary energy consumption (Söderholm and Wårell 2011). At the demand side, a range of measures must be put in place to adapt end users to low temperature operations. Some of these examples include implementing under-floor heating, fan-convector units, and radiators suitable for low-temperature systems. When the market is unable to send a price signal through heat prices, it is impossible to incentivize energy efficiency investments made by heat end users through energy savings.

Split Incentives Between Heat Companies and Excess Heat Producers

District heating companies have an incentive to invest when they can capture the benefits of energy efficiency improvement. When a third party, such as an industrial plant, accesses the district heating network, this incentive may be split due to the separation of distribution and production functions. From the heat network operator's perspective, lowering the return water temperature implies an extra cost for network infrastructure adjustment. Meanwhile, this will improve the ability to capture excess heat from industrial plants through larger temperature difference, which will in contrast lead to higher remuneration for heat producers. When energy efficiency gains cannot pay for the infrastructure improvement investments, heat companies may lose the incentive to give heat network access to excess heat producers (IEA and TU 2015). Financial return is often at the core of the split incentive. For heat companies and excess heat producers there is a negative correlation on the payback period from the return water temperatures, resulting in a clear split incentive regarding the return water temperature.

In order to address this split incentive issue, one solution consists of setting up a predefined return water temperature threshold in the heat supply agreement. Whenever the real return water temperature remains below this threshold, the threshold will be used to calculate the temperature difference for remunerating the heat producer. In such a way, the heating company's incentive to reduce the return water temperature will be not undermined. Based on preliminary analysis of pilot projects in the PRC, it is recommended to use the temperature of 44–45 °C which can result in a payback period of 3.5 years for both heat companies and excess heat producers (TU 2018).

Third-Party Access
Unbundling an vertically integrated utility company is considered as a key measure of liberalizing the electricity market through increased competition. In particular, production is considered suitable for competition in a well-functioning electricity market. However, this is less common in the heat market, because the municipality-owned heat utilities usually tend to prefer local heat producers and exclude third-party heat suppliers, partially due to the geographical constraints.

Although the PRC government has a large stake in district heating systems and heavily regulate heat tariffs, the provision of heat services has been commercialized progressively and the district heating market now becomes open to the private sector. Similar to the deregulation of electricity and natural gas markets in many countries, the participation of the private sector challenges the natural monopoly characteristics of municipal-owned heat companies with more competition (Wissner 2014).

The government may choose to regulate third party access in a nondiscriminatory way. The actual costs of transmission and distribution will largely vary depending on the characteristics of local sites. In addition, heat utilities may cross-subsidize transmission and distribution activities with inflated production costs. This information gap between the government and heat utilities will further complicate the harmonization of conditions and standards regarding third-party access.

Heat Resources Mapping
Heat planning is at the center of the interconnected energy system with multiple heat sources, as the central authority needs to guide the developments of local markets and decisions in order to support regional and national ambitions. Acknowledging this interconnectedness also means implementing policies, incentives, and support to ensure the adequate guidance on a local level to steer the implementation.

The heating system is under-dimensioned in big municipalities such as Beijing and Tianjin, while mostly larger than necessary to meet the current heat demand in medium and small-sized cities. When the heating system operates at partial capacity, costs are greater, losses are higher, and service quality suffers. In such a context, there is a need for heat planning that accounts for available heat supply, current and projected heat demand, and system planning priorities.

Since excess heat is a by-product of industrial activities, any industrial policy to reduce or shut down energy-intensive industries will affect the availability of heat source supply and impose uncertainty on the long-term financial viability of investments. In such as context, the heat planning can greatly help address this uncertainty.

Heat mapping in the PRC is currently mainly modelled with only few heating technologies. Improved heat mapping should also include more detailed information on the heat demand profile including building type, size and weather data. The improved heat mapping can thus enable decision making on clean energy solutions.

A master plan including technical and economic analysis of the heat potential from excess heat can be formulated. By using the master plan as a reference, utilities, municipalities, and private actors can then propose business cases to support the implementation of energy efficiency investments. If a common methodology is used, business cases can then be compared and decided on through an open-tender process, ensuring the development of the district heating system in the most cost-effective manner.

9.3 Business Models to Enhance Energy Efficiency of District Heating

A business model includes a blend of ownership, financing, and revenue that provide value to the customers. In this section, we suggest three business models including (i) a utility-led with third-party access model (ii) a heat production competition model, and (iii) an energy service company (ESCO)-integrated model. We provide case studies to highlight to what extent each business model has enabled energy efficiency financing in district heating markets.

9.3.1 Utility-Led with Third-Party Access Model

District heating is mostly characterized as a natural monopoly due to high fixed costs in the network infrastructure. A single supplier can supply the entire market at lower cost than several smaller suppliers because of economies of scale. Heat utility companies traditionally adopt an vertically integrated structure to deliver production, transmission and distribution activities. To some extent, an vertically integrated utility has the advantage to internalize the energy efficiency benefits between heat generators and distribution network operators. However, it is noted that an integrated utility model has some trade-offs with local public debt capacity, lack of innovation, and monopoly behavior.

District heating requires long-term planning and financing given high fixed costs. In the PRC, the source of financing for new heating infrastructure traditionally comes from connection fees paid by real estate developers, who ultimately pass on the costs to heat end-users. To enable the integration of industrial excess heat in the heat networks, municipalities may need to invest in laying additional pipes and renovating existing networks. With a stake in the natural monopoly, municipalities can play a role in securing the heat market demand through regulations on the connection of existing and future buildings with a district heating system.

In addition, an integrated structure can facilitate a system approach for energy efficiency improvement, since the utility will have more incentives to consider the heat system as a whole and not just one heat source. Due to the omnipresent split incentives in the district heating sector, this system approach can help ensure operational and economic efficiency in the long run, and pass on benefits of lowering heating costs to customers if properly managed.

In the utility-led with third-party access model (Fig. 9.4), a heat utility will need to negotiate an access agreement with excess heat producers. Since industrial excess heat provides a low marginal cost of heat supply, a monopoly heat utility will be able to benefit from lowering its production cost, in exchange for financing total or partial investments associated with heat source connection, particularly additional network costs. When the excess heat increases the risks of existing heat capacities being replaced, the conditions of the third-party access must provide enough incentives for the market entry of new heat sources and incentivize capital expenditure of utilities in energy efficiency improvement (IEA 2016b).

In this integrated business model, it is essential to provide third-party access to district heating networks in a nondiscriminatory way. Otherwise, a vertically integrated heat monopolist often has financial incentives to discriminate against new heat producers and to favor its own heat generators. The government will need to encourage the application of integrated resource planning to look for the most cost-effective and highly efficient clean sources.

It is widely recognized that the monopoly market will need outright price regulation. Since the government provides subsidies to fossil fuels such as coal and natural gas, price signals cannot allow industrial excess heat to compete on equal footing with other fossil fuels. Therefore, heat utilities may lose the economic incentive to allow access of the low-cost and clean heat sources to the networks.

Heat utilities can be required to meet an energy efficiency obligation or emissions reduction obligation. This market design helps incentivize district heating

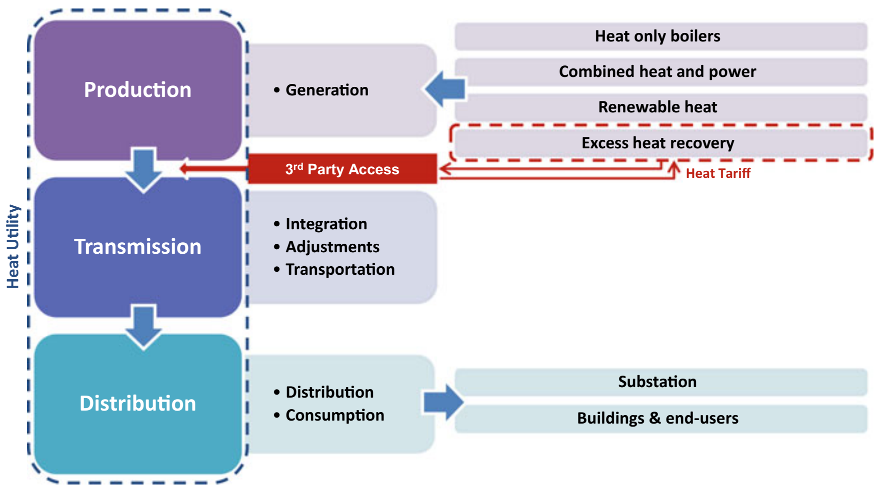

Fig. 9.4 Utility-led with third-party access business model. *Source* Authors' own elaboration

utilities to negotiate with industrial facilities to deliver the excess heat to the networks. Energy savings can be exchanged as a commodity through a market-based approach between utilities and other energy end users. Existing experience from the European Union's Energy Efficiency Directive show that the market is usually backed by the legislation requiring utilities to increase annual energy savings through energy efficiency measures (Euroheat and Power 2012).

The excess heat to district heat project could be partially financed with the central government grant with requirements of matching funds provided by local municipalities. The use of industrial excess heat in district heating systems often generates significant environmental benefits beyond the municipality administration scope. The central government intervention, in terms of financial transfer across regions, is necessary to internalize benefits of air pollution reduction and emissions reduction.

The case of Qingdao city provides an example. The municipality aims to replace a coal-dominant energy system with a clean and low-temperature district heating network. Instead of coal, Qingdao decided to use natural gas, solar, ground geothermal, and excess heat recovered from industrial plants to power its district heating systems.

The project is implemented by the Qingdao Energy Group, wholly owned by the Qingdao municipal government. The local government has requested a loan of $130 million with a 25-year term including a grace period of 5 years, from the Asian Development Bank. The Qingdao Energy Group finances $133.6 million through equity contribution. The project has installed small-scale natural gas boilers, an excess heat recovery system from sewage plants and industries, heat pump systems, a solar heating system, a heat storage system, and low-temperature pipelines in eight locations across the city. The project is expected to benefit 420,000 people through improved air quality and savings in households heat bills (ADB 2020).

To make use of industrial excess heat, Qingdao municipality imposes a zero-purchase price of industrial excess heat for the purpose of district heating services. Meanwhile, the municipal government also implements energy efficiency standards in buildings and sets a cap on energy consumption of its district energy system. As shown in Table 9.1, providing district heating simply with natural gas, geothermal, and solar thermal technologies will lead to a net financial loss. With the support of zero cost industrial excess heat, the overall project indicates a financial

Table 9.1 Financial internal rate of return with various fuels as heat sources in Qingdao project

Heat source	Financial internal rate of return
1. Natural gas	–1.5%
2. Shallow ground geothermal	Negative
3. Solar thermal	Negative
4. Excess heat utilization	24%
Overall	*10%*

Source ADB (2020)

internal rate of return of 10% because of savings in fuel costs. In the absence of industrial excess heat, the project would not have been economically viable.

9.3.2 Heat Production Competition Model

Heat production can be unbundled from heat transmission and distribution to enable competition among multiple heat sources (Fig. 9.5). If well managed, this competition can encourage energy efficiency improvement and cost-effective solutions in district heating systems. Two general forms of unbundling exist—ownership separation and accounting separation. While the ownership separation is set to establish an independent network operator effectively, the heat market must be advanced enough to play a primary role in pricing heat sources, because the government's role will be limited to correcting any market failures through monitoring and prevention of market power abuse (World Bank and ESMAP 2012).

This level of the maturity of the heat market is not usually met in many developing economies. Consequently, accounting separation provides an alternative, in particular when the ownership of heat transmission lines may be fragmented among several parties. The regulator can require heat utilities to unbundle the accounting of production, transmission, and distribution in order to increase the market transparency on network system costs. This functional separation can help reinforce the competitive nature of heat production. However, it may not completely remove the incentive of heat utilities to discriminate the third-party access of industrial excess heat. The regulator can determine the *ex-ante* access provisions. If

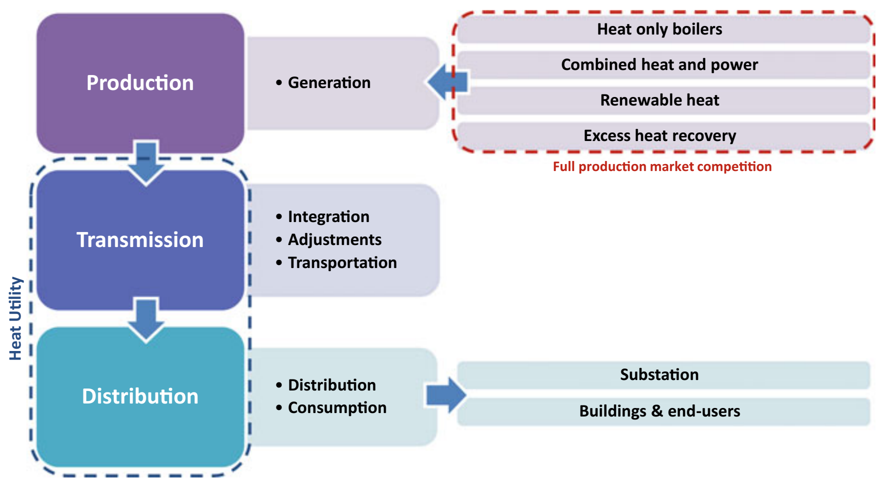

Fig. 9.5 The heat production competition business model. *Source* Authors' own elaboration

these preconditions are met by heat producers, the transmission operator is obliged to provide access to the network (Chittuma and Østergaarda 2014).

It is important to define least-cost supply requirements and ensure transparent and nondiscriminatory tendering process for procurement of heat sources. A publicly-owned entity is in charge of procuring heat from private heat producers and selling heat to distributors for on-sale to end users. This so-called single-buyer model can help transit from an vertically integrated utility model to a full market-based competition in the district heating market. Similar to the electricity market, this heat production competition model must establish licensing rules to encourage private investments in heat generation and dispatch least-cost heat supply options.

The Nordic countries have largely adopted this model in their district heating markets. For example, the main characteristic of the heat market in Denmark consists of a nonprofit policy. The municipalities own the transmission and distribution networks, but they buy heat from CHP, waste incineration plants, and industrial excess heat suppliers. The nonprofit policy is expected to make heat utilities charge customers on a cost-covering basis and avoid the market power abuse.

In the context of the PRC, significant investments for extension and retrofit of heat pipelines may be required to exploit large-scale industrial excess heat. To fill in the financing gap, the public–private partnership (PPP) is a useful tool to unlock the private sector investments. The PPP typically allows a private entity to provide a public service for a period of time in exchange for a reasonable financial return. This involves a contract between a public-sector authority and a private investor. The main purpose of the PPP is to allocate the tasks and risks to the private sector best able to manage them (ESMAP 2008).

The experience of Anshan city in the PRC provides some meaningful insights. Anshan city has seen the heat market traditionally dominated by a few dispersed public and private district heating companies. District heating has heavily relied on inefficient coal boilers. On the other hand, the city hosts one of the largest steel producers, known as Angang, in the country. The city has decided to tap into 1 gigawatt potential of industrial excess heat produced by the Angang steel plant to heat 50 million m^2 of building floor area, representing 70% of the total heating area. To achieve this target, a new transmission line to capture excess heat from the Angang steel plant and integrate it into the heat networks is needed. Under a PPP framework, this transmission line has been invested 60% by the government-owned Qianfeng district heating company, and 40% by Fu An, a private company. The transmission line has also anticipated connecting geothermal resources and two CHP plants with the heat networks in the future. The coal boilers are expected to be used only to meet the peak load demand occasionally. In this case, the partnership between the municipality and the private sector has succeeded in unlocking the investments in the transmission lines, which have enabled utilization of industrial excess heat from steel manufacturing process which would have been wasted otherwise (UNEP 2015).

9.3.3 ESCO-Integrated Business Model

An energy service company (ESCO) can drive private investments in energy efficiency by linking heating companies and industries (Fig. 9.6). This business model typically uses an energy performance contract to implement an energy efficiency project. The cost savings derived from energy efficiency improvement is the source of the ESCO's revenue to repay the project investments. In this business structure, the ESCO needs to negotiate with industrial excess heat producers, the heat utility and potential third-party financiers.

The private sector plays a leading role in enabling this business model. An ESCO can create an agreement with an excess heat provider either through shared savings or guaranteed savings contracts. Under a shared savings contract, the costs savings are split with a predefined percentage, while under a guaranteed savings contract, the ESCO guarantees a certain level of energy savings. One important difference between the two models is that the performance guarantee is the level of energy saved, while the shared savings are based on the cost of energy saved (IEA 2014).

Over the last years, ESCO investment in the PRC has increased by around 30% per year to reach €53 billion (CNY371 billion) and achieve annual energy savings of 124 million of standard coal equivalent. The number of ESCO firms has increased by 6 times from 782 in 2010 to 5426 in 2015, creating cumulatively 607,000 thousand jobs in 2015 compared to 175,000 in 2010 (IEA 2016a). However, the ESCO development in district heating market is still at an initial stage, partially due to the market challenges outlined earlier.

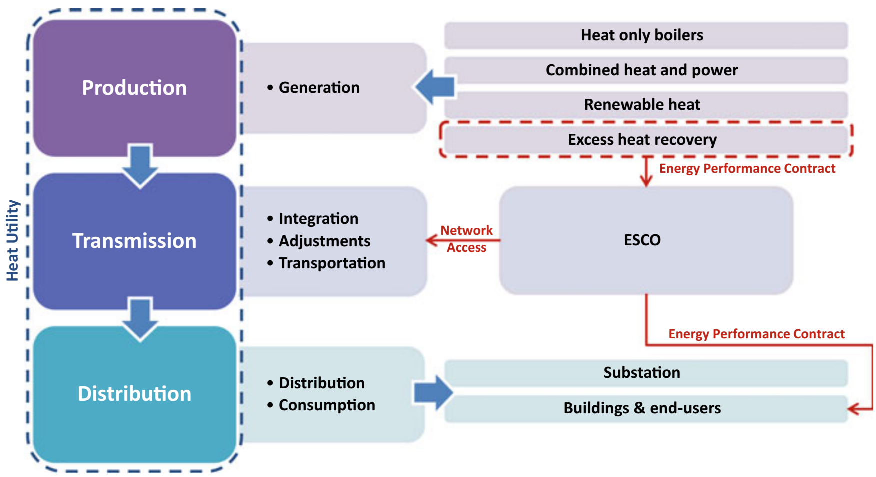

Fig. 9.6 The ESCO-integrated business model. *ESCO* energy service company. *Source* Authors' own elaboration

It is worth noting that, although an ESCO is usually wholly owned by the private sector, the government's role is still important to remove regulatory and policy barriers by addressing split incentives and facilitating access to finance (Retallack et al. 2018). Due to the supply uncertainty of excess heat as an industrial by-product, ESCOs face challenges of mobilizing long-term financing from commercial sources. The local government's guarantee is in many cases requested by ESCOs to secure project financing.

Regarding ESCOs' financing options, ESCOs assume the entire performance and technical risks under a guaranteed savings contract. For this reason, ESCOs rarely cover the investment repayment risk, and thus the project is typically financed by industries through corporate or project finance. The investment payment schedule may be adjusted by the level of savings: the higher the savings, the quicker the repayment. If the guaranteed savings are not achieved, the ESCO has to cover the debt service difference. In a newly established ESCO market, most actors may not have enough credit history and can only enter the market if the industry secures financing on its own. On the contrary, under the shared savings contract that shifts partial performance risk to industry, an ESCO is more likely to provide third party financing or co-invest with industry. It therefore assumes both performance and the underlying customer credit risk (IEA 2014).

The PRC's heat market provides some interesting ESCO cases. For instance, Qianxi district is an area with a population of around 390,000 and located in the eastern part of Tangshan city. District heating has historically been fueled by coal-fired boilers. Growth in building floor area has put an upward pressure on the heat supply, while Qianxi has been facing restrictions on coal consumption due to the environmental target.

A demonstration project was developed in 2014 in Qianxi to recycle excess heat from two new steel plants for district heating purposes. The project aims to reuse three categories of industrial excess heat: cooling water of the blast furnace, flushing water of the blast furnace slag, and mixed steam from basic oxygen furnaces and rolling heating furnaces. A study estimated this excess heat source potential at around 217 megawatts, which is able to serve the heat baseload up to 2030.

The ESCO, Qianxi Heran Energy Conservation Company, created a joint venture with the local government. This newly established district heating company concluded a concession agreement with the local district heating agency. It also established long-term contracts of purchasing industrial excess heat with the steel plants. The ESCO then signed an energy performance contract with the district heating network operator with the shared savings approach. The ESCO was in charge of providing third-party finance for project investments.

The project has three planned phases. The total investment for the first phase is approximately CNY283 million, including excess heat transmission pipelines within the steel plants and beyond, heat recovery equipment, and a new heating station. The second and third phases are expected to cost additional CNY51 million and CNY110 million, respectively. Once completed, the project is expected to reduce annual district heating costs by around CNY63 million by 2030. The overall project's payback period is estimated to be 7 years (IEA 2016b).

9.4 Pricing Industrial Excess Heat

In the PRC, pricing industrial excess heat is not an easy task. First, the presence of fossil fuel subsidies prevent the market from sending right energy price signals. Second, the close interlinkage of economic performance among production, transmission, and distribution activities further complicates the pricing mechanism to translate the system benefits across destring heating market players. In this section, we suggest four options of pricing industrial excess heat as follows:

(1) Estimating system costs
(2) Free-cost excess heat
(3) Establishing clean heat targets
(4) Indexing against the next best alternative

Option 1: Estimating System Costs
The first option is to regulate the price of excess heat with a systemic approach as shown in Fig. 9.7. This requires a holistic consideration of fixed and variable costs, back-up system costs, balancing costs, the potential impact on CHP plants, and the integration of renewable energy (Liu et al. 2020).

Specifically, the production costs reflect investment cost, fuel cost, operation and maintenance cost, and indirect costs such as environmental externalities due to air quality damage (SO_2, NO_X, and $PM_{2.5}$) and CO_2 emissions.

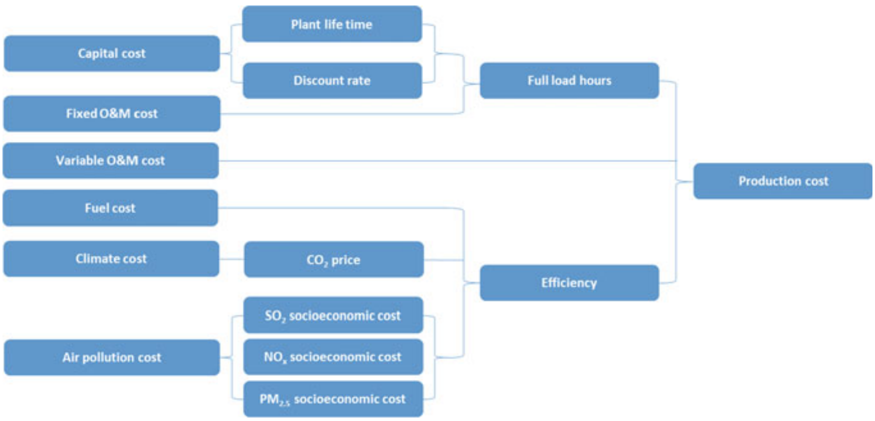

Fig. 9.7 The heat market production cost structure. *O&M* operation and maintenance. *Source* Authors' own elaboration

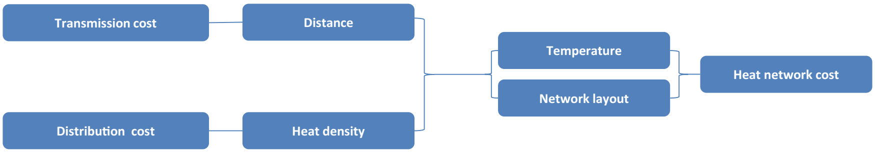

Fig. 9.8 The heat market network cost structure. *Source* Authors' own elaboration

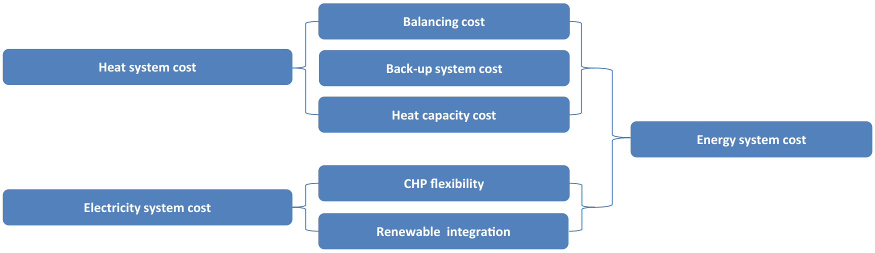

Fig. 9.9 The heat market system integration cost structure. *CHP* combined heat and power. *Source* Authors' own elaboration

As shown in Fig. 9.8, the network cost is typically related to transmission and distribution, which highly depend on distance and heat density, respectively. Similarly, temperature requirements, network layout and size have significant impact on this cost as well.

The system integration costs include the costs of new heat and electricity infrastructure, costs of integrating intermittent renewables into the energy system, and costs of balancing unpredictable heat and power sources. System costs are collectively determined by the configuration of the heat and electricity systems, and the penetration level of excess heat (See Fig. 9..9.9).

Option 2: Fee Cost Excess Heat

When the government is not ready for or capable of quantifying the costs and benefits from the system perspective, an intermediate approach entails implementing a free cost policy since the excess heat is viewed as a byproduct of industrial manufacturing process.

As illustrated in Sect. 9.3.1, district heating utilities can make use of free cost excess heat to integrate more options of clean heat sources. Given high capital costs of heat networks, this free cost policy can help strengthen the financial viability of the investments made by a natural monopoly heat utility. Meanwhile, the government may consider establishing an energy efficiency obligation, and/or a clean energy target. With a nonprofit and social equity objective, this option can further allow passing on the financial gains derived from utilization of free-cost excess heat to the heat end-users.

Option 3: Establishing Clean Heat Targets
For the third option, the government can create a market-based instrument by setting an obligation on heating companies to diversify clean heat sources. This will incentivize heat companies to explore the most cost-effective clean heat sources. Similar to the EU Emissions Trading System or Green Certificates for renewable energy, clean heat targets enable sending a price signal of industrial excess heat to the market players.

To date, over 23 cities in the PRC have committed to peaking their emissions earlier than the country-wide peak target by 2030. They have formed an Alliance of Peaking Pioneer Cities, which represent one-quarter of the PRC's urban carbon emissions. Improving the efficiency of the district energy systems is a major policy initiative to meet their climate change commitment.

Option 4: Indexing Against the Next Best Alternative
Excess heat is typically explored to replace a more expensive fuel that would otherwise have been used in district heating networks. The heat price of this alternative fuel can provide a good metric against which is benchmarked excess heat price. The heat market must monitor heat production costs to settle the reference price for industrial excess heat.

While an alternative heat source in the counterfactual scenario may not be easily discovered, the regulator can also price industrial excess heat at a certain percentage discount of the least expensive heat production cost. To mitigate excessive fluctuation for excess heat prices, the regulator can set up price caps, below which the price-setting will be more driven by the market and less reliant on regulatory oversight (Euroheat and Power 2012).

9.4.1 Impact of Industrial Excess Heat on District Heating Prices

Opening the heat market to excess heat producers will increase competition and incentivize more energy efficiency investments. However, the extent to which the consumer's heat prices will change remains an open question. The size of the heat market and the number of competing firms are important for choosing an appropriate pricing policy (Söderholm and Wårell 2011).

In the PRC, the district heat sector is highly fragmented with many local heat suppliers. Consolidation of district heating within and across cities is expected to bring about benefits of economy of scale, and optimize the dispatch of clean heat sources. Indeed, the entry of new market players can increase the market competition. Nevertheless, when the competition is limited by the presence of few dominant market players, heating utilities may have a strong incentive to inflate the system costs of introducing industrial excess heat in order to cross-subsidize their own production and distribution activities (Söderholm and Wårell 2011).

Most cities in the PRC apply a fair rate of return policy with two-pars pricing: a regulated network price and a market price for the delivered heat (Söderholm and Wårell 2011). This two-part pricing structure has the advantage of reconciling production efficiency and financing incentives.

On the one hand, the increasing penetration of industrial excess heat in the district heating network can lower marginal cost of heat supply. These savings in operational costs are expected to put downward pressure on heat prices. On the other hand, introducing industrial excess heat may also imply additional costs of retrofitting and balancing heat networks. The net heat prices may still increase as a result of capital intensive infrastructure investments.

9.5 Conclusions and Policy Recommendations

Examining the heat market as a system enables the identification of system opportunities and challenges for energy efficiency investments. We identify three business models to enable increased financing for low-grade excess heat utilization. Getting the heat tariff right is elemental for translating the system benefits to the market value. The following policy implications arise from our analysis.

First, the government authority should make low-grade excess heat visible in energy statistics. For this, there is a need to develop guidelines to help local authorities qualify and report the potential for district heating and any additional costs of using excess heat. The heat resources mapping is expected to identify industrial clusters and assess heat supply and demand across regions. This will allow the assessment of transmission distances between excess heat producers and near-by district heating networks.

Second, the PRC should enhance the utilization of low-grade excess heat as a structural energy efficiency measure. The national energy authority can develop a guideline on cost–benefit analysis of a range of clean heat solutions. The country must consider multiple options of integrating heat and power sectors, such that the system costs and benefits can be better understood. This will support the market with a scientifically sound analysis to shoulder investments in energy efficiency improvement of district heating.

Third, the government needs to improve third-party access to district heating networks. The key measures include promoting transparency of heat network pricing, reinforcing the competition of heat production, and improving the PPP concession bidding. It is also important to establish least-cost dispatch requirements and enhance investors' appetite for clean heat options.

Last but not least, the government will need to review current public support measures for energy efficiency investments in district heating. Given the inherent uncertainty due to the industrial excess heat and complex institutional arrangements, the government may provide guarantee funds or risk-sharing facilities, thus enabling the private sector to access commercial loans. The policy package also includes harmonizing pricing policies related to air pollutants, carbon emissions, and fossil fuel subsidies.

Although our study is specific for the PRC, the policy and financing issues are global opportunities for improving energy efficiency in district energy systems. For future research, market mechanisms to integrating heat and power sectors for improved energy efficiency merit further investigation.

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Chapter 10
Market-Led Energy Efficiency Transformation in India: A Deep Dive into the Perform, Achieve, Trade (PAT) Scheme

Gopal K. Sarangi and Farhad Taghizadeh-Hesary

Abstract To sustain the high economic growth trajectory of India, it becomes imperative that an adequate supply of energy is maintained over a long period. One such major initiatives is the thrust laid on energy efficiency interventions as a low hanging option for meeting the overarching energy and climate goals of the country. In this context, the present chapter focuses on analyzing market-based approaches for energy efficiency interventions, with specific thrust on the perform, achieve, and trade scheme. While mapping of energy efficiency policies points to the gradual transitioning from a regulatory regime to a market-based arrangement, analysis of the perform, achieve, trade scheme indicates that while the scheme is designed in a dynamic manner and has huge energy saving potential, lack of clarity at the policy level, and operational anomalies could generate dampening effects on future energy efficiency investments. Policy streamlining becomes much imperative for the successful implementation of this scheme.

Keywords Energy efficiency · Market-based instruments · Energy-saving certificates · India

JEL Classification L94 · Q48 · Q49

10.1 Background

India is one of the fastest-growing economies of the world and increasingly assuming a pivotal role in the global energy market. To sustain the ongoing high economic growth trajectory of the country, it is imperative that an adequate and

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reliable supply of energy is maintained. However, because of heavy reliance on fossil fuel sources, Indian energy sector emerges as the single largest source of greenhouse gas emissions, contributing more than 65% of the total emissions in the country. Recent transformative changes ushered in the sector with specific thrust on renewable energy and energy efficiency initiatives can drive the energy sector on a sustainable growth path and can become an effective mechanism to decouple energy from negative climate repercussions.

The Government of India has taken several proactive policy steps to drive the energy system towards a secure, affordable, and sustainable growth trajectory. It posited that the current energy policy thrust of the government revolves around four pillars of energy development: provisioning of modern energy access to all, lessening of energy intensity through a host of policy and market-led energy efficiency initiatives, achieving sustainability of energy sector through the acceleration of renewable energy generation, and enhancing energy security (Sokolowski 2019). These developments correspond with global developments and India's global commitments to achieve sustainable energy.

The importance of energy efficiency as a strategic solution to the majority of energy sector challenges is well documented. The primacy of energy efficiency rests on its ability to mitigate adverse climate impacts as well as arresting mounting energy demand. Often energy efficiency initiatives are considered to be panacea to the persisting challenges of India's energy sector. Even globally, there has been defined thrust laid on energy efficiency as an untapped low hanging energy option to achieve the desired energy and climate goals. For instance, Target 7.3 of Sustainable Development Goal (SDG) 7 points to the importance of energy efficiency by stating that "doubling of the global rate of improvement in energy efficiency by 2030". For India, it gets even more pronounced, given the fast-rising economic growth and its consequent impact on surge in energy demand and its implications on climate change. It is posited that the easiest pathway to achieve the energy goals and combating climate change conundrums would be to capitalize on energy efficiency (Sahoo et al. 2016). It merits to highlight some of the emerging trends in India's energy sector, which establishes the imperative to lay thrust on energy efficiency as a decisive policy action.

One such feature of India's energy sector is the rise in energy demand, which can be attributed to a host of recent developments. Recent transformations in the socioeconomic profile of the Indian population has significant implications for the energy demand in the country. Projections reveal that there will be around 140 million middle-income households and around 21 million high-income households added to the existing numbers by 2030, which point to the emergence of a new Indian middle class (WEF 2018). Scholarly writings analyzing the future electricity demand offer nuanced understanding of such transformations and consequent impact on electricity demand mediated through the acquisition of high energy-guzzling assets (Wolfram et al. 2012; Gertler et al. 2016; Gupta et al. 2020). For instance, India is projected to have 1 billion air conditioning units by 2050, which can significantly escalate electricity demand. This corresponds with the growing pace of urbanization in the country. India's urban population is estimated to touch a new high of 814 million by 2050, which could further escalate the demand for energy-guzzling appliances. In addition to the above, recent efforts to electrify all willing households can unleash a huge pent up latent demand, stimulating further growth in energy demand.

Energy-saving potential estimates in the country point to the magnitude of possible energy saving through energy efficiency interventions. For instance, estimates by the Bureau of Energy Efficiency (BEE) (2019a) reveal that energy-saving potential in both moderate and ambitious policy scenarios are estimated to be 87 million tonnes of oil equivalent (toe) and 129 million toe, respectively by 2031, constituting around 10% to 15% of total energy consumption in the country. Projections by the International Energy Agency (IEA) (2020) unfold that the implementation of energy efficiency programs can lower the energy intensity in the country by 875 terawatt-hours of electricity per year, which could translate roughly into savings of around $190 billion per year in terms of less energy imports for the country by 2040. Highlighting the energy-saving potential of specific energy using assets in the country, Parikh and Parikh (2016) present that if low cost financing is availed, key energy appliance types such as air conditioners, refrigerators, color television sets, and ceiling fans have the potential to save around 40% of total electricity use.

The importance of energy efficiency could also intricately be associated with strategic policy efforts to decouple climate change from energy. The IEA estimates suggest that steps undertaken by India in the energy efficiency space has led to the avoidance of an additional 15% annual energy demand between 2000 to 2018 and have saved 300 million tonnes of CO_2 emissions during the same period. It is estimated that the implementation of energy efficiency policies in the country could reduce about 36 % of greenhouse gas emissions by 2050 (Kumar et al. 2012).

The thrust of the chapter is to examine how energy efficiency policies in the country have evolved to create a market based regime for the sector. It conducts a detailed mapping of the perform, achieve, and trade (PAT) scheme as a market-based instrument and assesses its evolution and implementation modalities. The chapter also throws light on the financing of the PAT scheme and challenges associated with the operationalization of the scheme. The analytical contours of the chapter are drawn from the available secondary information and data.

The chapter is structured as follows. Section 10.2 offers a nuanced understanding of the energy efficiency policy landscape of India as it has evolved in a phased manner. Section 10.3 highlights the current energy consumption patterns and their implications for the energy intensity of the country. Section 10.4 maps recent studies on the PAT scheme. Section 10.5 conducts a detailed assessment of the PAT scheme. Section 10.6 highlights the modalities of energy efficiency financing, with specific context of the PAT scheme. Section 10.7 presents the inherent challenges for the uptake of energy efficiency interventions in the country. Section 10.8 concludes the chapter.

10.2 Policy Landscape Governing Energy Efficiency Initiatives in India

The policy landscape for energy efficiency in India unravels some worthwhile dimensions of energy policy making in India. While electricity sector policy making has attracted wider publicity and much research focus, it appears that energy efficiency policy making has evolved silently over years and acts as one of the key drivers in transforming the energy sector in the country. A careful mapping of energy efficiency policies indicates that it revolves around the emphasis on regulation, market transformation, fiscal policies, incentive-based policy instruments, awareness creation, among others. Although historically, energy efficiency and energy conservation initiatives can be traced back to the 1970s as a response to the global oil crisis, conservation efforts during those days were primarily intended to minimize the consumption of petroleum fuel (AEEE 2011). The real thrust on energy efficiency was heralded with the promulgation of the Energy Conservation Act 2001.

Energy efficiency policy making in India is structured around three different phases, starting from the enactment of the Energy Conservation Act 2001 until today, not quite disconnected rather evolved in a sequential manner. The first phase is a period of voluntary standards and labeling. The second phase is linked to the emphasis on market-based transformation for energy efficiency interventions. The third phase is the deepening of market-based energy efficiency interventions and transiting from voluntary to mandatory standards. The details of such phased policy evolutions are presented below.

Phase I (2001–2007): Period of Voluntary Standards and Labeling
Phase I of energy efficiency policy making is linked to the pronouncement of the Energy Conservation Act 2001, which laid down the foundation for energy efficiency policy making in the country. A dedicated institution called the Bureau of Energy Efficiency (BEE) was created in 2002 to promote energy efficiency goals in the country. The BEE was recognized as a nodal agency to develop strategies, policies, and programs; gather and analyze relevant data; generate awareness; disseminate information; promote research and development activities; develop testing and certification procedures; and promote innovative financing instruments for energy efficiency projects. Policy making in phase I is characterized as largely motivational, promotional, and voluntary in nature. The primacy was assigned to a set of general standards for energy consumption, carrying out energy audits, etc.

The standards and labeling program, as one of the flagship programs of the BEE was launched in 2006 in this phase, which continued to be a thrust area of the BEE even today. The approach is to set efficiency standards for products on a voluntary basis, with the premise that once it achieves a certain degree of market penetration and maturity, these standards will gradually be converted into mandatory standards. It prescribes limits on energy consumption by setting standards for applicable equipment and appliances. The approach was to rate products on a scale of 1 to 5, where 5 is assigned to the most energy-efficient products and 1 is assigned to the least energy-efficient products. The scheme was aimed at empowering consumers by providing the information needed to make informed decisions about their energy consumption of electrical equipment and appliances as well as cost-saving potential. Energy efficiency standards were set for 19 types of equipment and appliances initially during this period.

Similarly, the Energy Conservation Building Code (ECBC) was introduced during this phase in 2007 to achieve the minimum performance standards of buildings. This was designed under the premise that electricity use in buildings is rising fast, and needs to be curtailed. The emphasis initially was to improve the building code of commercial buildings. Star ratings of these buildings are carried out on a 1–5 scale, 5 being the most energy efficient and 1 being the least energy efficient. The measurement is based on the energy use in the buildings over their area, usually measured as kilowatt hours (kWh) per square meters per year. Initially, buildings having a connected load of 500 kW or contract demand of 6,000 kVA were part of this scheme.

In addition to the above, agricultural demand-side management (AgDSM) and municipal demand-side management (MuDSM) were also introduced in 2007–08, to reduce the energy intensity of the agriculture sector and the municipal sector. In the agriculture sector, it is estimated that around 21 million grid-connected conventional irrigation pump sets consume 187 billion kWh of energy every year, which can be converted into high-efficient pump sets. Similarly, the municipal sector possesses a huge potential for energy saving. These are key policy and program level initiatives undertaken in the first phase.

Phase II (2008–2015): Market-Led Energy Efficiency Initiatives

Phase II is linked to the declaration of the National Mission for Enhanced Energy Efficiency (NMEEE) as part of the eight missions declared under the National Action Plan on Climate Change. This phase is characterized by the acceleration of energy efficiency initiatives through market-led approaches and interventions. Necessary legal provisions were created to infuse elements of the market in achieving the energy efficiency goals by amending the Energy Conservation Act 2001.

In phase II, institutional innovations occurred in the form of setting up of Energy Efficiency Services Limited (EESL), a joint venture of four government-owned companies designed to implement the market-related energy efficiency interventions envisaged under the NMEEE. The NMEEE has four major components: (i) the PAT scheme, (ii) market transformation for energy efficiency (MTEE), (iii) the energy efficiency financing platform, and (iv) the framework for energy efficient economic development. The NMEEE had set a target of achieving energy efficiency by saving 23 million tonnes of oil equivalent through avoided generation capacity of 19,000 megawatts (Bhandari and Shrimali 2018).

Several other energy efficiency initiatives were undertaken and promoted through the MTEE in this phase. The Bachat Lamp Yojana (BLY) scheme was designed to act as a catalyst for market transformation, making a shift from the compact fluorescent lamp (CFL) bulb market to the light emitting diode (LED) bulb market, by using the concept of economies of scale. Another similar program was the Super-Efficient Equipment Programme (SEEP) strategized to usher market transformation by offering financial stimulus. Under this program, ceiling fans are identified as a possible low hanging energy efficiency option, by replacing conventional 75 w ceiling fans with energy efficient 35 watt (W) ceiling fans.

The ECBC was amended in this phase with emphasis on a larger set of buildings (GOI 2010).

Phase III (2016–till now): Deepening of Market Transformation Initiatives and Transition from Voluntary to Mandatory Energy-Efficient Schemes
Greater emphasis in this phase is laid on the acceleration of market transformation and transiting from voluntary schemes to an increased number of mandatory energy efficiency products.

The Standards and labeling program, has now expanded to cover 26 appliances (BEE 2019), with 10 as mandatory appliances. One successful implementation of the standards and labeling program in this phase is the use of super-efficient appliances through affordable prices by employing the scale economies concept. The Bachat Lamp Yojana and the Super-Efficient Equipment Programme scheme introduced in phase II are further strengthened in this phase. By the end of December 2019, about 350 million LED bulbs and 2.3 million highly-efficient fans had been sold in the country under these schemes (Thapar 2020).

The AgDSM was further promoted through pilot schemes and programs. Under the AgDSM program, 2,200 old and inefficient irrigation pump sets were replaced by energy-efficient star rated pump sets. Similarly, under the MuDSM, energy audit and energy consumption optimization were made mandatory under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme. The latest statistics reveal that BEE now covers 175 municipalities under this program through the process of energy audits and preparation of detailed project reports (BEE 2019b). These are implemented through the energy service company (ESCO) mode. Similarly, the EESL Street Lights National Programme, introduced in 2015 has been a game-changer by replacing 5 million street lights, spread across 500 cities in the country, saving around 1.35 billion kWh of energy.

The ECBC program is further expanded its scope with its second version announced in 2017, which is a revised and stringent code having three levels of compliance compared to the earlier version. In this new scheme, a building can secure higher grades compared to the ECBC such as ECBC+ or super ECBC status. Emphasis is given to include the residential sector as well. Toward this, the Eco Niwas Samhita, Part I Building Envelope (Energy Conservation Building Code for Residential Sector) was launched in 2018 to set minimum standards of buildings. This code is now applicable to residential buildings with a minimum plot size of 500 square meters or above. In addition, the Energy Efficiency Label for Residential Buildings was introduced in 2019, which compares houses based on energy efficiency performances of such houses.

Other efforts in this phase include strengthening of the capacity of distribution companies (DISCOMs) in the sphere of load management, the development of demand side management (DSM) action plans, and the implementation of various DSM schemes. The BEE has carried out the capacity building program of DISCOMs in two phases. In the first phase, 34 DISCOMs were selected and provided the necessary capacity building for enhancing their energy efficiency levels. In the second phase, which led to the setting up of DSM cells in these 34 DISCOMs, DSM regulations were announced by these DISCOMs spread across 23 states. As part of the DSM action plans, load surveys have been carried out. In the second phase, the remaining 28 DISCOMs have been included in the program, and necessary actions were taken for them too.

10.3 Trends and Patterns of Energy Intensity in India: A Snapshot

Having highlighted the energy efficiency policies and programs in the last section and their evolution and development, it merits to throw light on the present energy consumption scenarios and energy intensity growth trends in the country. This could reflect achievements made in the field of energy efficiency and gaps that require further acceleration of energy efficiency initiatives.

A nuanced understanding of the scope for energy efficiency requires the mapping of energy consumption and their patterns. Such a mapping of sectoral electricity consumption in the country over the last 8 years is presented in Fig. 10.1. It can be gleaned from Fig. 10.1 that industrial consumption holds a large chunk of the total electricity consumption with around 40% of total electricity consumption in the country. Although there has been a marginal deceleration in industrial electricity consumption in last couple of years, it is more or less consistent over time. The 2nd next highest share is with the domestic sector, which shows a marginal rising trend from 22% in 2011–12 to 24% in 2018–19. This could be due to large-scale household electrification undertaken recently, spurred by pro-active household electrification schemes like *saubhagya*. The share of agricultural consumption in the total consumption stands almost stangnant close to 18% for the entire duration, although the exact electricity consumption by the agriculture sector is doubted, as most of this consumption is unmetered and hence, largely unaccounted. Commercial electricity consumption revolves around 8%–9%.

It is worth highlighting the key implications derived from sectoral electricity consumption. A higher share of industrial energy consumption reveals that there is a need to identify energy-intensive industrial units and devise appropriate policy action plans to minimize the energy consumption of such units. In that direction,

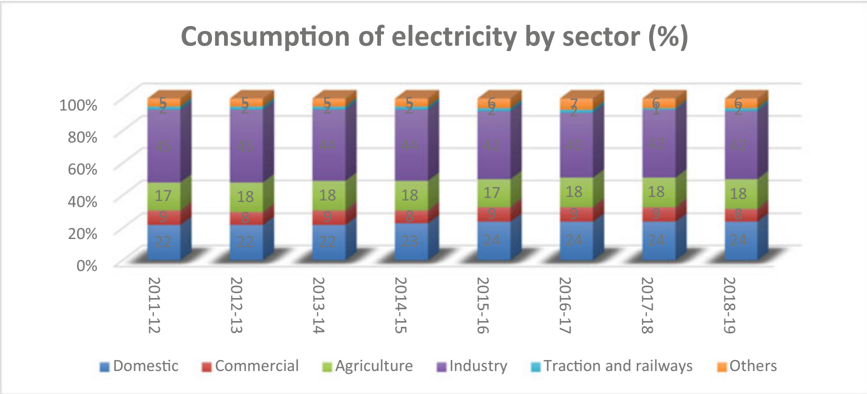

Fig. 10.1 Consumption of electricity by sectors (%). *Source* Authors' compilation, from different volumes of India Energy Statistics

a market-based mechanism through a perform, achieve, and trade (PAT) scheme is a well-designed scheme to achieve industrial energy efficiency goals. The second important implication is entrenched with the political economy of tariff settings for industrial consumers. In India's context, some consumer categories—largely industrial and commercial consumers—pay tariffs significantly higher than the average tariffs. It acts as a deterrent and forces them to have either their captive power plants or buy from the open market. Sustained efforts to improve energy efficiency could offer a win–win solution for both. Increased share of residential consumers could be attributed to the recent uptake in the household electrification and subsidized provisioning of electricity for the sector through policy initiatives such as *Saubhagya* scheme. It is also projected that there would be a substantial jump in household electricity consumption in future due to the rise in the middle class and a consequent growth in the acquisition of electrical appliances over. All these point to the imperative to design effective energy efficiency incentive schemes and mechanisms for the residential sector.

The next important aspect is to highlight the energy intensity trends for the country. Figure 10.2 reflects the trends of energy intensity (measured by dividing total primary energy with the gross domestic product [GDP]) for the last 14 years starting from 2005–06 to 2018–19. It can be gleaned from Figure 10.2 that there has been a decline in the energy intensity over the period. This could primarily because of a faster rate of growth in GDP compared to energy demand, increasing share of the tertiary sector in the economy, and energy efficiency interventions. The growth rate shows that there has been a 47% decline in energy intensity over the 14 years. This highlights the gradual decoupling of energy consumption from the growth rate. This is a positive sign for the economy. Energy intensity trends also indicate that there has been a significant drop in the energy intensity in the year 2011–12. It has dropped from 0.457 to 0.274.

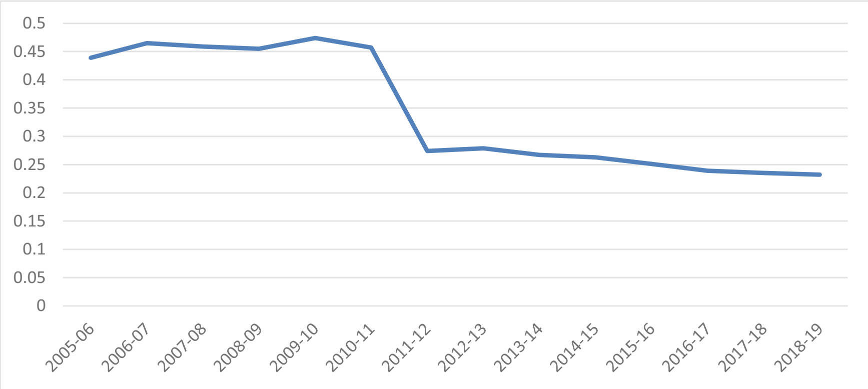

Fig. 10.2 Energy intensity trends. *Source* Authors' compilation from different volumes of India Energy Statistics

Studies point out that efficiency gains are largely confined to the industrial sector and service sector and also to some extent due to residential buildings. However, it is posited that efficiency gains are offset by increased energy consumption, a rise in appliance ownership, among others, which is projected to further escalate in the future. These indicate that huge scope exists to improve the energy efficiency performance in the country.

It emerges from the above that, industrial consumption continues to dominate the energy consumption in the country. Although the PAT scheme is designed to target reduced industrial consumption, and has been operational close to a decade, there has not been significant reduction in the share of industrial consumption both in absolute terms or in relative terms. It merits in this context to deep dive into the PAT scheme to understand the processes and assess the progress made so far. Before, the chapter carries out a detailed mapping of the PAT scheme in Sect. 10.5, the next section captures the existing literature on the PAT scheme.

10.4 Perform, Achieve, and Trade (PAT) Scheme: Brief Review of Scholarly Writings

The transformation in the energy efficiency policy making in the country with its emphasis on the implementation of market-based instrument of the PAT scheme has attracted wider scholarly attention from the conceptualization stage until today, focusing on a variety of implementation aspects of such a scheme. One of the earliest studies on the PAT scheme, specifically focused on the detailed assessment of the functioning of the Energy Savings Certificates Schemes (ESCerts) envisaged under the PAT scheme and identifies key success conditions of such a scheme (Bhattacharya and Kapoor 2012). It posits that the primary objective of the PAT scheme is to attract the much sought after investment for the sector. The paper argues that the scheme suffers from a host of policy level uncertainties. On a similar vein, Kumar and Agarwala (2013) comparatively assess the design issues of both renewable energy certificates and ESCerts under the PAT scheme. It suggests that that both schemes could work in an interactive mode along with international mechanisms like the clean development mechanism (CDM).

Two studies specifically focused on issues such as target setting, baseline fixation, and compliance options under the PAT scheme. In a scholarly piece, Sahoo et al. (2017a) examine the effectiveness of the PAT scheme by assessing the rationality of target setting under the scheme. The rationality and possibility of free riding by some plants are tested by employing the data envelopment analysis method to a set of 71 thermal power plants in the country. It concludes that there exist huge levels of inefficiencies both in energy use and managerial practice of such plants, and hence suggests the need for tighter targets and revised baseline fixation. In another similar study by Sahoo et al. (2017b) compliance options available to meet the set of energy efficiency targets under the PAT scheme are analyzed for thermal power plants. Findings of the study offer optimal compliance choices for the chosen plants based on uncertain ESCerts prices and clean coal premium. Considering two different thermal power plants as the case study—one efficient versus an inefficient one, the paper concludes that the PAT scheme has the potential to drive the investment in the inefficient plant compared to the efficient one. Sahoo et al. (2018) in a similar vein carry out a detailed analysis of target setting and normalizing aspects under the PAT scheme in the thermal power plant context. Assessing whether operating conditions of thermal power plants do impact specific energy consumption of thermal power plants, the study concludes that varying operating conditions do impact the plant performance, hence are to be accommodated in the normalizing process. Bhandari and Shrimali (2018), in an analytical study, examine the effectiveness of the PAT scheme and suggests that targets set under the PAT scheme are not adequate to attract long-term investment in the energy efficiency projects. It suggests that there in a need to re-estimate the baseline and set it at a more realistic level.

It emerges from the review that while some important aspects of the PAT scheme such as target setting, baseline formation, and compliance options have received scholarly attention, there has been short shrift in comprehensive mapping of the scheme and assessing its evolution trajectory. The present chapter is an attempt to fill the void by carrying out a detailed mapping of the scheme, its evolution, and implementation modalities.

10.5 Market-Led Energy Efficiency Transformation in India: The Case of the PAT Scheme

Market-based mechanisms to achieve energy efficiency goals are not new, rather they have been popular in many other countries such as the United Kingdom, Italy, France, and Australia. Ideally, market-based instruments should be built around five key elements such as setting the overall target, designing a framework for identifying obligated entities, apportioning targets within the obligated entities, a methodology for allocating certificates, and framing rules for market transactions. Within these five key elements, the overall target setting should be given foremost importance. Toward this end, necessary energy efficiency policy actions were introduced in 2012 through the introduction of the PAT scheme as part of the declaration of the NMEEE.

The scheme was designed to improve the energy efficiency of industrial units in a cost-effective manner. It was based on the premise that the industrial sector, although a dominant energy consuming sector in the country, has not been able to tap the benefits of increased energy efficiency so far due to limited access to capital to fund energy efficiency projects, and often the lack of incentives for such investments, coupled with inadequate information of the benefits of energy efficiency investments (Bhandari and Shrimali 2018). The PAT scheme was designed to mitigate such inherent anomalies and offer a transparent, robust, and cost-effective market mechanism to attain the desired energy efficiency goals. The PAT scheme is a multi-cycle program launched in 2012, which combines elements of the market and governed within broader regulations of the BEE. The goal is to reduce the specific energy consumption in most energy-intensive industries in the country. This section offers a critical mapping of the PAT scheme.

The scheme gets operationalized through a series of cycles, with a duration of 3 years each. The process involves identifying sectors and designated consumers (DCs) in each sector to be part of this scheme. The assessment procedure is to carry out the assessment of specific energy consumption for each DC in the base year and project the specific energy consumption in the target year. The accounting process takes into consideration various forms of energy used in the plant and products leaving the plant in a cycle. This is called the “gate-to-gate” concept, where all the energy consumption at all stages of production is taken into consideration while estimating the current consumption. A deep dive into the process reveals that the mode of operation is to set the target reduction based on their current energy consumption. Hence, energy-efficient DCs will have lower targets compared to their lower energy-efficient counterparts. The process also has a system of normalization, where deviations occurred due to external factors accommodated which are beyond the control of the DCs. The excess energy savings by the designated consumers are converted into tradable certificates.

The market mechanism operates through the trading of certificates known as ESCerts, where designated consumers those who have overachieved their targets would be credited through assigning with the ESCerts, whereas the underachievers

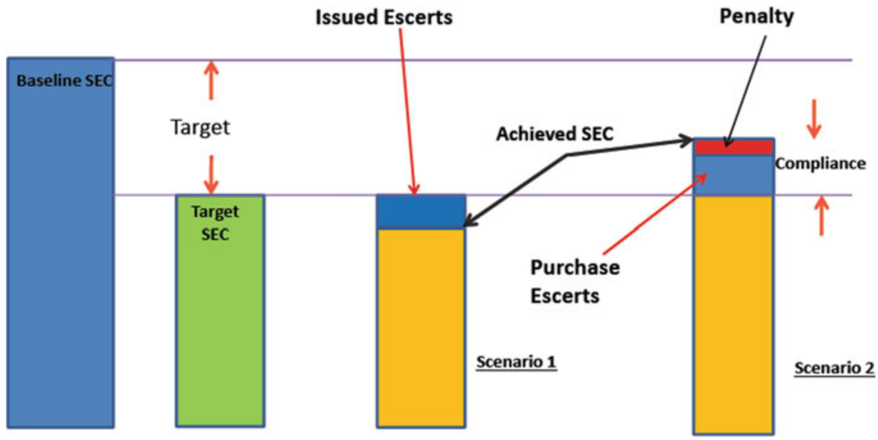

Fig. 10.3 Mechanism of trading ESCerts. *Source* BEE (2017)

would be penalized (Figure 10.3). These certificates are tradable commodities that give rights to the holder certain amount of energy savings though an intangible manner. Each certificate possesses a value of 1 megawatt hour (MWh) of energy savings. The BEE and the EESL are the authorized government entities for the issuance of ESCerts. Once ESCerts are issued, they are traded in the power exchanges. The prices of such certificates are market determined. Although the regulatory constraints work in the form setting targets, from a regulatory point of view, it is required that targets should not be set at a very low level, which would crash the market by generating surplus ESCerts. Conversely, targets should not be so stringent that it is cumbersome to achieve or attain the same, which would jeopardize the purpose.

The trading history of ESCerts unfolds that energy savings accrued to the DCs during the first cycle of the PAT scheme (2012–13 to 2014–15) have been converted into certificates and traded through the national trading platform, the Indian Energy Exchange (IEX) in 2017–18. A total number of 3.82 million ESCerts were issued during the first phase to 306 DCs who had overachieved the targets, whereas 110 DCs who could not achieve their targets had to purchase ESCerts of about 1.42 million ESCerts from the market to meet their set targets. The trading occurred through the mechanism of a double-side uniform price auction. The market price discovered through trading fluctuated widely over the trading period, ranging from a low of ₹200 per ESCerts to a very high of ₹1,200 per ESCerts (Figure 10.4). Unlike renewable energy certificates (RECs), ESCerts do not have forbearance and floor prices.

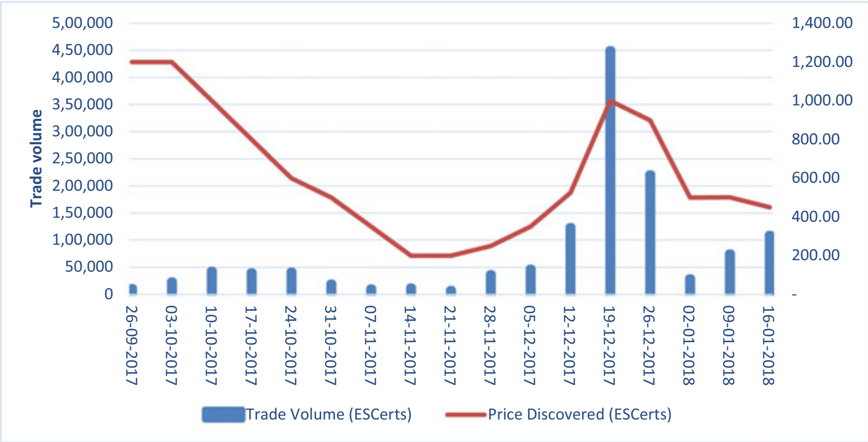

Fig. 10.4 ESCerts trading volume and price discoveries (₹). *Source* Authors' compilation

The latest statistics reveal that 956 energy-intensive industries of designated consumers from 13 sectors have been identified for the adoption of energy efficiency measures (BEE 2019b). Through this scheme, it is projected that there would be saving of about 22 million tonnes of oil equivalent (Mtoe) and 70 million tonnes of CO_2 by 2022 (BEE 2019b). The details of cycles are presented below and in Table 10.1.

PAT Cycle I: 2012–13 to 2014–15

The very first cycle which got implemented from 2012 to 2015, targeted 478 industrial units spreading over eight sectors. This cycle led to an energy savings of 8.67 Mtoe, which is equivalent to reducing about 31 million tonnes of CO_2. Although the target was set low at 6.68 Mtoe, it overachieved the target. These designated consumers were 1) aluminum, 2) cement, 3) chlor-alkali, 4) fertilizer, 5) pulp and paper, 6) power, 7) iron and steel, 8) textiles, and 9) railways. These sectors together constitute around 60% of the energy consumption in the country, which is equivalent to 231.6 Mtoe amount of energy. One of the major loopholes in the first phase was that certificates were issued ex post and hence could not provide the needed price signals to attract the investment. Energy savings secured in Cycle I were converted into energy-saving certificates of about 3.825 million ESCerts to 30 DCs, those who overachieved their targets (BEE 2019b).

PAT Cycle II (2016–17 to 2018–19)

Since the PAT scheme was implemented on a rolling cycle basis, every cycle identified a new set of DCs and sectors. In Cycle II, 621 DCs were identified in 11 energy-intensive sectors. These sectors consist of three new sectors along with three new sectors: railways, refineries, and DISCOMS. The energy-saving target set in this cycle was in the tune of 8.86 Mtoe.

Table 10.1 PAT cycles, coverage, DCs, sectors, and energy-saving targets

Cycle	Duration	Coverage of PAT scheme		Energy-saving targets (Mtoe)	Sectors covered
		Number of sectors	Designated consumers (in units)		
I	2012–13 to 2014–15	8	478	6.68	Aluminum, cement, chlor-alkali, fertilizer, iron and steel, pulp and paper, textile, thermal power
II	2016–17 to 2018–19	11	621	8.86	Aluminum, cement, chlor-alkali, fertilizer, iron and steel, pulp and paper, textile, and thermal power, railways, refineries, DISCOMs
III	2017–18 to 2019–20	6	116	1.06	Aluminum, cement, iron and steel, pulp and paper, textile, thermal power
IV	2018–19 to 2020–21	8	109	0.69	Aluminum, cement, iron and steel, pulp and paper, textile, and thermal power, petrochemicals and commercial buildings (hotels)
V	2019–20	8	110	0.51	Aluminum, cement, chlor-alkali, iron and steel, commercial buildings (hotels), pulp and paper, textile, and thermal power

DC designated consumer, *DISCOM distribution company, Mtoe* million tonnes of oil equivalent, *PAT* perform act, trade. *Source* Authors' compilation

PAT Cycle III (2017–18 to 2019–20)

Given the overlapping nature of the duration of these cycles, the number of identified DCs in sectors had been reduced in this cycle. A total number of 116 DCs are identified across six energy-intensive sectors. Energy savings targets set in this cycle was of about 1.06 Mtoe.

PAT Cycle IV (2018–19 to 2020–21)

Cycle IV commenced on 1 April 2018 when an additional 109 DCs were identified from the existing sectors and two new sectors of petrochemicals and commercials buildings (hotels) were added. An energy-saving target of 0.69 Mtoe was kept being achieved in this cycle.

PAT Cycle V (declared in 2019–20)
Cycle V commenced on 1 April 2019. 110 DCs from the existing sectors were identified spread across eight key sectors. It is projected to have an energy-saving of 0.51 Mtoe.

Up to April 2019, there were four cycles of the PAT scheme, consisting of 956 DCs spread across 13 sectors. An analysis of the PAT scheme points to the fact that the scheme is designed on a dynamic manner to tap the energy efficiency potential of industrial units. Over the years the scheme has deepened by increasing the number of DCs and widened by covering more sectors. The introduction of a trading mechanism has ushered a new regime in the energy efficiency domain in the country. However, there are some inherent challenges in the designing of the scehme and implementation of it. A lack of clarity at the policy level could hinder future investments. In addition, there have been questions raised with regard to the targets set, fixation of baselines, and compliance options provided to the designated consumers (Sahoo et al.2017a,b; Sahoo et al. 2018; Bhandari and Shrimali 2018). This could create dampening effects on future energy efficiency investments.

10.6 Financing Energy Efficiency Projects

There is a critical need for financing energy efficiency projects given their importance for the sector and for the sustainable development of the country. Despite the fact that energy efficiency interventions are relatively inexpensive and are easily scalable compared to large-scale power projects; these projects have not been taken up at the desired scale. It is argued that most of the energy efficiency benefits continue to be untapped due to inadequate and poor investment delivery mechanisms (Kumar et al. 2012). This is primarily due to poor financing of energy efficiency projects by the banking, non-banking and other financial institutions. The problem gets compounded as energy efficiency projects are largely undertaken by the private sector in the country and hence, rely more on market based financing.

This section maps existing financial mechanisms and financing instruments that exist in the country to support energy efficiency projects largely by industrial sector. A list of such mechanisms and instruments that are in place is presented below.

10.6.1 Energy Efficiency Financial Platform

This is an initiative undertaken as part of the NMEE to get engaged with financial institutions and developers for the implementation of energy efficiency projects. A memorandum of understanding has been signed by the BEE with various financial institutions as well as nonbanking financial institutions to promote energy efficiency projects through training and capacity building exercises. The most recent initiative in this space is the Investment Bazaar for Energy Efficiency set ups in four regions in the country. In addition , to promote and accelerate energy efficiency financing at the state level, state-designated agencies are instructed to constitute state level committees to attract the necessary energy efficiency financing.

10.6.2 Framework for Energy Efficient Economic Development

Under this scheme implemented as part of the NMEE, two important financing programs have been launched: the Partial Risk Guarantee Fund for Energy Efficiency and the Venture Capital Fund for Energy Efficiency. In the Partial Risk Guarantee Fund for Energy Efficiency program, support is provided to address the debt related challenges faced by energy efficiency projects. It is a risk guarantee instrument, with partial coverage of risks guaranteed to the financial institutions involved in extending loans to energy efficiency projects. Similarly, the Venture Capital Fund for Energy Efficiency program is designed to facilitate last-mile equity investment for the energy efficiency projects, limited to a maximum of 15% of equity. This support is for government buildings, private buildings, and municipalities.

10.6.3 Concessional Financing through IREDA

Indian Renewable Energy Development Agency Limited (IREDA) offers concessional financing for end user efficiency retrofit projects, DSM projects by utilities, projects facilitated by ESCOs, and projects developed under the PAT scheme. This funding comes in the form of concessional loans, where project developers can draw loans up to 70% of the project cost for installing energy efficiency equipment. A variety of sectors are covered under this funding scheme. In addition to the above, credit lines are provided to commercial banks for financing of energy efficiency projects at a low rate of interest.

10.6.4 State Energy Conservation Funds

The Energy Conservation Act 2001 mandates states to constitute State Energy Conservation Funds (SECFs) to facilitate the financing of energy efficiency projects. The key goal of SECFs is to address the barriers faced by energy efficiency projects by supporting energy audit subsidies, by facilitating interest buydown schemes, and by offering partial risk guarantees. A total of 27 states have established SECFs. Although a majority of states have constituted this fund, they have not been provided the necessary financial support to energy efficiency projects (World Bank 2016).

10.6.5 ESCO-Based Financing

Energy service companies (ESCO) based financing has emerged as a successful financing mechanism for the financing of energy efficiency projects. The modalities of this kind of funding reveal that the upfront financing is extended through ESCOs, whereas companies or beneficiaries payback the through their reduced energy bills (Kumar et al. 2012). In India, ESCOs play an important role by providing savings guarantee, taking risks in the implementation of energy efficiency projects, and by performing measurement and verification (M&V) activities. There are around 150 ESCOs empaneled with the BEE. ESCOs are trained by the BEE to understand and facilitate the energy efficiency financing, M&V protocols, develop skillsets to estimate the baseline, and mitigate the risks associated with energy efficiency projects.

Despite efforts undertaken to promote the financing of energy efficiency projects, there exist a lot of barriers to attracting the necessary funding for these projects. One such barrier is the indifferent attitude by the banking community for these projects, primarily because of a lack of confidence with the commercial banks about funding and bankability of energy efficiency projects and lack of awareness among banking communities of the associated benefits of energy efficiency investments (BEE 2019b). This further gets accentuated due to the small size of the projects resulting in high transaction costs, high perceived business, and technical risks. Project-based financing by banks is often found to be suitable for large infrastructure projects, where banks secure cash flows as collateral. However, due to inherent challenges associated with cash-flow based financing, it does not serve the purpose of funding the energy efficiency projects. The nature of energy savings resulting from energy efficiency investments often acts as a deterrent for cash-based financing of energy efficiency interventions. Hence, it is crucial at this juncture to correct the entrenched anomalies in attracting the necessary financing and drive the sector on a sustainable development trajectory. One such initiative which could act as a game changer is the need for detailed audits and transparent reporting of energy efficiency projects to ascertain the baseline levels and associated energy and cost savings, that could be accrued due to energy efficiency interventions. Setting the baseline, hence, becomes a critical first step for attracting bank finance. In addition to that, there is a need to develop proper M&V protocol to minimize the transaction costs. The next section highlights some of the key challenges associated with energy efficiency interventions in the country.

10.7 Obstructions for Uptake of Energy Efficiency Interventions under the PAT Scheme

The uptake of energy efficiency initiatives is deterred by several factors, often interconnected and intertwined.

One such challenge is associated with the institutional framework governing energy efficiency interventions in India. As these interventions spread across an array of sectors, necessary support systems must exist to implement such projects. This, coupled with the lack of proper monitoring and evaluation, often leads to suboptimal outcomes. Periodic monitoring and evaluation of policies and plans of BEE are not mandated by the act, hence often acts as a major constraint for the success of energy efficiency projects. It has been reported by studies that monitoring of energy efficiency projects is often neglected, resulting in poor implementation of such projects.

Policy-level inconsistencies and lack of clarity have become major bottleneck for the successful implementation of energy efficiency projects (Singh et al. 2012). For instance, new buildings come under the ECBC, whereas energy efficiency initiatives for old buildings are dealt with through the PAT scheme. Similarly, overlapping of PAT cycles often creates confusion among all the stakeholders. Often policy level inconsistencies are accentuated by the lack of adequate capacity at the sub-national scale.

It is argued that the targets set under the PAT scheme are lenient, and hence could be easily achievable. For instance, a study analyzing the rationality of the target setting for thermal power plants under the PAT scheme showed that their targets could have been much stringent (Sahoo et al. 2017a). Similarly, it is posited that targets set under the PAT scheme are not adequate enough to attract long-term investment in energy efficiency projects, hence need to be set at more realistic levels (Bhandari and Shrimali 2018). It is lamented that if targets are not set appropriately, it would lead to free riding problems (Sahoo et al. 2018). In addition, compliance options available to meet the energy efficiency targets under the PAT scheme are not clearly laid down, hence accentuate policy-level uncertainties. Similarly, policy-level hurdles are associated with the operation of ESCerts. As these certificates are issued ex post, i.e., after verification of reduction in saving, hence could not provide the right signal for energy efficiency investments and might have led to fluctuations in the price of ESCerts (Bhattacharya and Kapoor 2012). It is important to maintain the stability of ESCerts to attract the badly needed financial investment in energy efficiency projects. This could be addressed by setting a floor price for ESCerts that could reduce market uncertainties and could go a long way in attracting necessary capital for investment. There is no clarity with regard to the next round of trading of ESCerts, which creates ambiguity among the potential investors for the sector.

10.8 Conclusion

Growing energy demand combined with the need to combat threats of climate change have made it imperative to lay thrust on energy efficiency as a strategic solution to drive the country on sustainable growth path. In this context the chapter examines key market-led energy efficiency initiatives with specific thrust on the PAT scheme. In addition, it assesses existing set of financial instruments supporting the energy efficiency interventions in the country, and critically discusses some key challenges encountered.

It is found that energy efficiency policy making in India has evolved over three different phases, graduating towards market-led policies for the sector in recent years. While the first phase is characterized as a period of voluntary standards and labeling, the second phase is linked to the emphasis laid on market-based transformations as a key mechanism. The third phase is the phase of acceleration of market-based interventions and transitioning from voluntary regime to more of the mandatory regime of energy efficiency products and appliances.

A nuanced understanding of energy consumption patterns reveals that industrial consumption holds a large chunk in the total electricity consumption revolving around 40% of total consumption, implying that there is a need to prioritize this segment of the consumption as a potential sector for energy efficiency interventions. It clearly sets the foreground for the design and implementation of PAT scheme.

The analysis of the PAT scheme points to the fact that the scheme is designed in a dynamic manner to tap the energy efficiency potential of industrial units. The introduction of the trading mechanism has ushered a new regime in the energy efficiency market in the country. However, there are inherent challenges with the designing and implementation of this scheme. The lack of clarity at the policy level could hinder future investments. In addition, targets are set not at a stringent level, hence could be easily achievable. Easy target setting may create dampening effects on future energy efficiency investments.

From the overall analysis, it could be elicited that a set of hurdles are encountered in driving energy efficiency goals in the country. Key financing barriers lie with the lack of confidence with the banking community about the bankability of energy efficiency projects. This further gets accentuated due to the small size of the projects resulting in high transaction costs, high perceived business and technical risks emanating because of poor understanding of such projects. It is suggested that proactive policy actions such as detailed audits and transparent reporting of energy efficiency projects can mitigate these challenges substantially. Other key challenges are low electricity prices, weak governance and institutional structures, lack of proper monitoring and evaluation, policy-level inconsistencies, and lack of clarity. It is clear from the analysis that strategic policy actions are needed at all levels to mitigate such challenges effectively.

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Chapter 11
Financing of Energy Efficiency in Public Goods: The Case of Street Lighting Systems in Indonesia

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Abstract Energy demand growth in Asian countries is predicted to be the highest in the world. One of the drivers of energy demand growth is urbanization. Along with growing urban areas, public infrastructure, such as streetlights, is also expanding. Unfortunately, energy conservation measures in public facilities are commonly constrained by the budget limitations of local governments, while the potential participation of energy service companies (ESCO) requires regulation reformation settling the contradicting regulations. This study proposes several policy recommendations to modify existing guidelines for selecting ESCOs for the energy efficiency of streetlights in Indonesia that has the highest urbanization rate. Regulation review and several potential improvements for selecting ESCOs are provided. In 2017, the Ministry of Domestic Affairs released a Circular Letter to solve barriers to ESCO businesses in public sectors; however, the Circular Letter could be improved in several ways by eliminating the clauses on the holder of intellectual property rights, revising the valuation of economic benefit bidding, and increasing the maximum contract period. Moreover, we propose the use of smart street lighting technologies to improve the value-added services of streetlights and the establishment of a super ESCO to accelerate ESCO business activity in all economic sectors.

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JEL Classification G18 · H54 · H57 · H70 · L94 · Q48

11.1 Introduction

Global energy demand is expected to increase by one-third from now until 2040 (IEA 2017). Countries from the Organisation for Economic Co-operation and Development will only contribute 4% of this growth. Of the remainder, the largest share will come from the emerging economies of Asia. In the 2020s, the emphasis will shift to India and then the countries of Southeast Asia as the key drivers of demand growth, while the pace of energy demand growth slows in the People's Republic of China (Liu et al. 2020). Among developing countries in Asia, Indonesia has the highest urbanization rate, which is the main factor in escalating electricity consumption in the country (WB 2016b; Al Irsyad et al. 2018). An urban area is linked to numerous home appliances used and public amenity availability, including streetlights. As an integral component of city development, streetlights support economic activities in the evening, improve road safety, reduce crime, and improve the city aesthetics; consequently, energy consumed by streetlights grows with development, increasing from 3 terawatt hours (TWh) to 3.6 TWh during 2010 to 2018 (PLN 2011, 2018).

Indonesia has the potential to reduce energy consumption from streetlights by 2.1 TWh per year, or by more than half of its existing consumption (Al Irsyad and Nepal 2016); however, most local governments have a limited budget and knowledge of energy efficiency. Cooperation with an energy service company (ESCO) is considered to be a solution and several ESCOs have an interest in energy conservation in street lighting systems. An ESCO provides a broad range of energy efficiency measures or services, mostly under energy performance contracting (EPC)—a financing technique that repays the cost of energy efficiency projects through the cost savings they produce. Global ESCO value in terms of EPC revenue expanded to nearly $30 billion in 2017, with the People's Republic of China (PRC) (60%), the United States (US) (20%), and Europe (10%) representing three major ESCO markets. Over 1 million people are now employed by ESCOs around the world. In Indonesia, several local governments experienced legal issues when using ESCO schemes, especially the shared-savings scheme. The problems related to a formula of cost-saving share for the ESCO and a perception that presumes the cost-saving share is a loan, which is prohibited for the municipalities. The Ministry of Domestic Affairs (MDA) released a Circular Letter in 2017 regulating the cooperation between local governments and ESCOs for energy efficiency (MDA 2017). The letter has regulated the main issues of the selection process and gives instructions to pay ESCOs for energy efficiency services and not for the energy efficiency investment. Despite this change, there remains room for regulation improvement since the existing regulation is ineffective and may lead to a monopoly in the energy efficiency market for street lighting.

The objective of this study is to review and improve the existing ESCO regulations for public utilities. The improvements are essential to maximize benefits for local governments as well as to expand ESCO business in countries that still struggle with financing energy efficiency. This chapter contributes to the literature by discussing two promising policies resolving barriers of ESCO business in developing countries. The first policy is a super ESCO defined as a state-owned institution appointed to undertake energy conservation projects in public infrastructure as well as to assist private ESCOs in expanding energy conservation markets. The second policy is the Circular Letter of the MDA for energy efficiency partnership (MDA 2017). The Circular Letter regulates that payments to ESCOs should be allocated in a special budget account to avoid prejudice of an ESCO contract as a loan that is prohibited. Nevertheless, the Circular Letter has several shortcomings and, therefore, the novelty of this study is to offer several improvements to increase the efficiency of the regulation.

The discussions of this study are structured as follows. Section 11.2 reviews global challenges for financing energy efficiency while Sect. 11.3 reviews policy in Indonesia for financing energy efficiency in public utilities. Section 11.4 discusses an ESCO case study in Indonesia and Sect. 11.5 discusses policy recommendations. Section 11.6 concludes this study.

11.2 Review of Global Instruments for Energy Efficiency

The main database used in this study is the Mesures d'Utilisation Rationnelle de l'Energie (MURE) database, including policy measures on energy efficiency (ISINNOVA 2020), as well as the International Energy Agency (IEA) policies and measures database (IEA 2020). These two databases have arguably the most comprehensive and updated collection of renewable energy and energy efficiency policies and measures across the world. To get an overview across the world, we integrated the policy measures from both the IEA and MURE databases.

The number of policy measures administered in the industrial sector is significantly smaller than in the building sector (about one-third fewer). Overall, policy measures used in the industrial sector focus on more complex and capital-intensive technologies compared to those of other sectors. This corresponds to the fact that the industrial sector is inherently more complex regarding energy efficiency improvements, both in terms of the number of potential measures as well as the complexity of the technology itself. Many energy efficiency improvements are catered to a particular sub-sector and cannot be standardized easily, as is the case in the building sector.

As of June 2019, the MURE and IEA databases contained a total of 860 industry measures, out of which 623 were in operation; the others (237) were either not active or were being planned out. Across the world, as shown in Fig. 11.1, 326

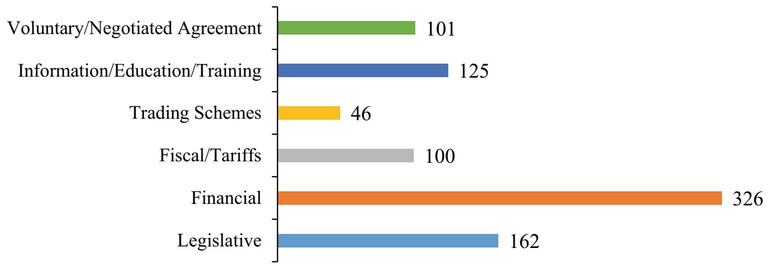


Fig. 11.1 Number of energy efficiency policy measures by type (across the world). *Source* ISINNOVA (2020)

financial measures (37.9%) form the core of the policy mix for the industrial sector, followed by legislative measures (162, 18.8%) and information/education/training (125, 14.5%). Voluntary/negotiated agreements (101, 11.7%), fiscal/tariffs (100, 11.6%), and trading schemes (46, 5.3%) are implemented less often in the industrial sector.

Compared to energy efficiency in the industrial sector, financing energy efficiency in the public sector is a challenge for both developed and developing countries due to the budget limitations of local governments. Even in developed countries like the United States (US), Wang et al. (2017) found that the majority of US cities did not have energy efficiency financing measures, while cities implementing energy efficiency financing measures still lacked energy efficiency investments. These findings result from the high investment cost, benefit uncertainty, and a long return on investment (Du Can et al. 2014). One solution is the involvement of technical expertise and professional companies, such as ESCOs, since this increases the confidence of citizens and local governments to implement energy efficiency measures (Wang et al. 2017). Appointing ESCOs through a bidding process is categorized as a market-based instrument (MBI) for energy efficiency (Rosenow et al. 2019). The bidding process aims to obtain competitive tenders among ESCOs to provide either the lowest bid or the highest energy savings.

The ESCO works by using an EPC so the payment to the ESCO will be adjusted according to the achievement of energy-saving targets. In general, there are two types of EPC: guaranteed savings and shared savings (compared in Table 11.1) (Pätäri and Sinkkonen 2014; Shang et al. 2017; Sarkar and Singh 2010; Larsen et al. 2012). In a guaranteed-savings contract, the ESCO acts as a contractor of an energy efficiency project, while the municipality will provide the investment costs. The ESCO will assure the achievement of energy-saving targets; otherwise, the ESCO will receive a penalty, such as a payment reduction. In a shared-savings contract, the ESCO is responsible for investment and maintenance costs; consequently, the benefits of electricity bill savings will be shared between the ESCO and the municipality at an agreed share and period. Both ESCO types have some common features, such as using a performance-based contract so the ESCO takes

Table 11.1 Comparison of the two types of EPC when using an ESCO

Parameter	Shared savings	Guaranteed savings
Investor	ESCO	Municipality/road administrators
Investment risk taker	ESCO	ESCO
Technical risk taker	ESCO	ESCO
Nontechnical risk taker	ESCO and municipality/road administrators	ESCO and municipality/road administrators
Investment returns	Performance-based contract	Performance-based contract
The value of benefit-sharing	ESCOs have a higher share than that of a guaranteed-savings contract	ESCOs have a lower share than that of a shared-savings contract
Contract period	Determined by municipality/road administrators	Determined by municipality/road administrators
Feasibility study	Funded by the ESCO or municipality/road administrators	Funded by the ESCO or municipality/road administrators

EPC energy performance contracting, *ESCO* energy service company. *Sources* Pätäri and Sinkkonen (2014); Shang et al. (2017); Sarkar and Singh (2010); Larsen et al. (2012)

all the investment and technical risks. The period of the contract is determined by the municipality or road administrator as the project owner. Both municipalities and ESCOs have nontechnical risks, such as rejection from the state-owned electricity company (PLN) who want to keep their higher electricity tariffs for unmetered streetlights in Indonesia (Al Irsyad and Nepal 2016).

EPC simultaneously helps companies to finance investments through future energy savings, and to bear the financial, technical, and performance risk (E3P 2020). EPC has been implemented in over 50 jurisdictions, including Brazil, the PRC, India, the Republic of Korea, and South Africa (WB 2016a). Developed and developing countries have different preferences when selecting the ESCO contract type. Developed countries mostly use the guaranteed-savings contract because it has lower transaction costs. In this case, the ESCO does not have to pay loan interest in financing the investment and, therefore, draws lower financing risks. In contrast, ESCO projects in developing countries mostly rely on a shared-savings contract since most developing countries have limited budgets and lack access to financing assistance.

The ESCO market remains undeveloped in many countries due to at least three main barriers. The first barrier is that the majority of ESCOs are not creditworthy enough to pursue the project pipeline (Larsen et al. 2017). Financing limitations are common among ESCOs and, at the same time, obtaining external funding encounters the problems of low awareness and motivation of financial institutions, lack of trust by stakeholders, and lack of successful project experience (Bertoldi and Boza-Kiss 2017). An on-off financial subsidy from the government is only worsening the market since an ESCO will only run the business if the subsidy exists but the subsidy will also attract inexperienced and undedicated ESCOs, creating a poor image of ESCO credibility (Kangas et al. 2018). The second barrier is a lack of technical capability of the ESCO and EPC firms. Capability is categorized into basic capability (e.g., identify, prepare, and procure technology), production capability (e.g., quality control, operation and maintenance), improvement capability (e.g., adaptation and modification), innovation capability (e.g., research, design, and development), and linkage capability (e.g., transfer of knowledge, skill, and technology) (Qiu 2018). The poor capability may occur in all process stages, from the planning stage to the monitoring and verification stage (Bertoldi and Boza-Kiss 2017; Kangas et al. 2018). A failed ESCO project will have severe consequences in terms of public trust and, thereafter, ESCO markets (Bertoldi and Boza-Kiss 2017). The third barrier is the uncertainty of earnings due to fluctuations in energy prices or electricity tariffs causing ESCOs to walk away from projects. Using a fixed energy price as the basis for savings calculations may hedge the price uncertainty with a consequence a lower profit if there are higher energy prices in the future (Stevens et al. 2019; Larsen et al. 2017).

Other energy efficiency financing measures are being continuously developed globally. In developing countries, among the five energy efficiency financing measures implemented in Malaysia, the rebate program is considered as the most cost-effective measure (Hor and Rahmat 2018). Nevertheless, Hor and Rahmat (2018) suggested to improve the rebate program by implementing on-bill financing, which is a more effective and efficient measure for a monopoly electricity market. Indonesia may carry out on-bill financing by ordering PLN, who monopolizes the electricity retail market, to act as a super ESCO that simultaneously provides electricity and energy conservation services. In this case, energy conservation service charges are included in electricity bills, although this will contradict PLN's main business interests, which are geared toward maximizing investment returns from PLN's existing power plants.

In this chapter, we define a super ESCO as an organization established by the government to implement energy efficiency projects in the public sector (e.g., hospitals, schools, municipalities, and public facilities) but also, simultaneously, to promote the development and growth of ESCOs in the private sector through capacity building, project development, facilitation, or financing, as well as creating new ESCOs (Limaye and Limaye 2011). As shown in Fig. 11.2, the government capitalizes super ESCOs with sufficient funds to undertake energy performance contracting in the public sector, as well as to leverage on commercial financing. As our priority is to build the technical and financial capacity of ESCOs and to grow the ESCO industry in Indonesia, neither a large ESCO nor a public ESCO is sufficient for meeting these requirements.

Most of the current super ESCO models are designed to undertake public sector energy efficiency projects, such as public buildings and public street lighting, to overcome the difficulties that traditional ESCOs face in working with the public sector (e.g., limited incentives for the public sector to lower energy costs, and complex and strict budgeting and procurement procedures). The main roles of super ESCOs are twofold: being an ESCO for the public sector and being an enabling

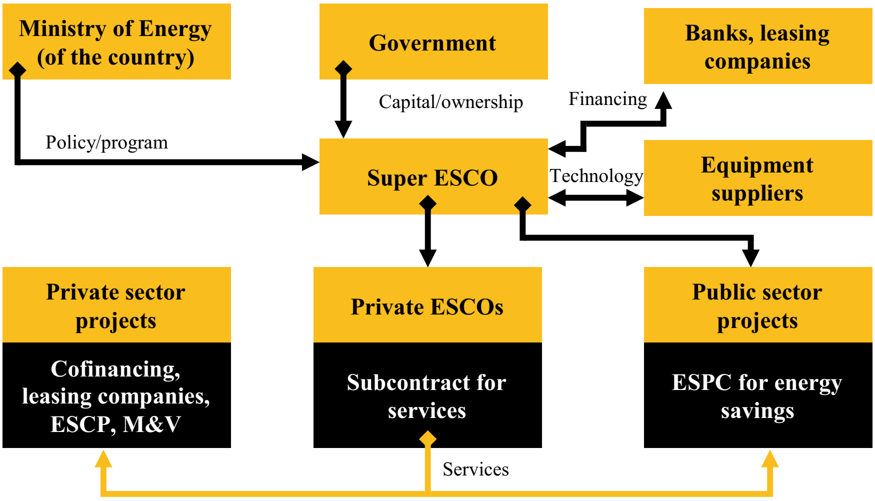


Fig. 11.2 An illustrative model of a super ESCO. *ESCO* energy service company *ESCP* Energy Saving Performance Contract *M&V* measurement and verification. *Source* Sarkar and Moin (2018)

partner for private ESCOs. A super ESCO can work directly with the public sector and industries to fill the gap in the following areas:

- Perform data analysis and benchmarking
- Identify energy-saving opportunities
- Design technical solutions and specifications, ranging from simple equipment replacement to industrial energy management
- Aggregate the demand for energy efficiency measures, entering into shared or guaranteed savings contracts through a pay-as-you-save approach with end users
- Conduct joint or independent measurement and verification of energy savings
- Recover investments from end users' monetized energy savings
- Operate and maintain the equipment and processes in the contract period as agreed with the end users

A super ESCO will also help create an enabling environment for private ESCOs with the following measures:

- Accredit domestic ESCOs and the energy management profession
- Engage private ESCOs as key delivery partners
- Arrange access to financing and risk-sharing facilities
- Demonstrate the viability of ESCO business models and help end users become more familiar with ESCOs
- Standardize technical specifications and transaction templates and tools to reduce the perceived risk of working with ESCOs
- Raise consumer awareness of energy efficiency and enable market demand for energy management

11.3 Policy Challenges in Indonesia

The Indonesian government has mandated energy efficiency measures in all sectors through Law 30/2007 on Energy (GOI 2007). Moreover, Government Regulation 70/2009 on Energy Conservation obligates energy users consuming 6,000-ton oil equivalent (toe)/year to conduct energy management and report its results (GOI 2009). These regulations and other forcing factors, such as energy price increases, have decreased energy intensity, as shown in Fig. 11.3. Final energy intensity decreased, on average, by 2.8% per year from 2010 to 2017, exceeding the target of 1% per year (GOI 2014); as a result, Indonesia is ranked as the third-lowest energy intensity among the Association of Southeast Asian Nations (ASEAN) members (Fitriyanto and Iskandar 2019).

Significant and massive energy efficiency measures started in the public sector between 2012 and 2014 when the Ministry of Energy and Mineral Resources (MEMR) conducted an energy audit on streetlight systems in nine municipalities and deployed pilot projects of high-efficiency streetlights in seven cities (Al Irsyad and Nepal 2016; Berlian et al. 2014; Ahadi et al. 2018). One of the measures is to use white-colored light-emitting diode (LED) lamps which are not reliable in foggy conditions. Replacing high-pressure sodium (HPS) lamps with LED lamps potentially reduces energy consumption by 50% (Ahadi et al. 2018). Successful pilot projects were then adapted by other municipalities so the average electricity consumption of a street lighting system reduced from 20,589 kilowatt hours (kWh) per year to 14,549 kWh/year, as shown in Fig. 11.4.

ESCOs are considered as an effective measure to accelerate energy efficiency in streetlights. The MDA released the Circular Letter for energy efficiency partnership

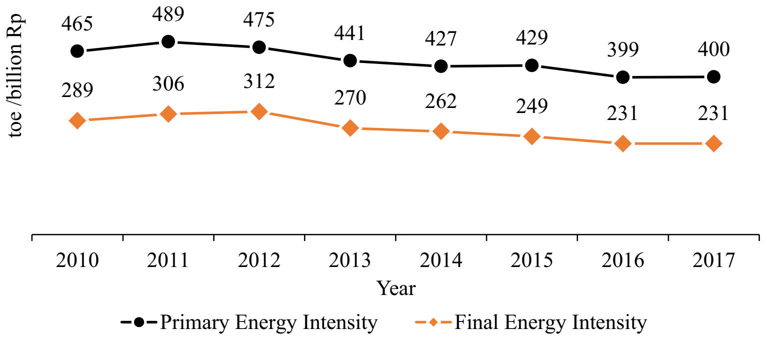


Fig. 11.3 Energy intensity in 2010 to 2017. *Source* DEC (2018)

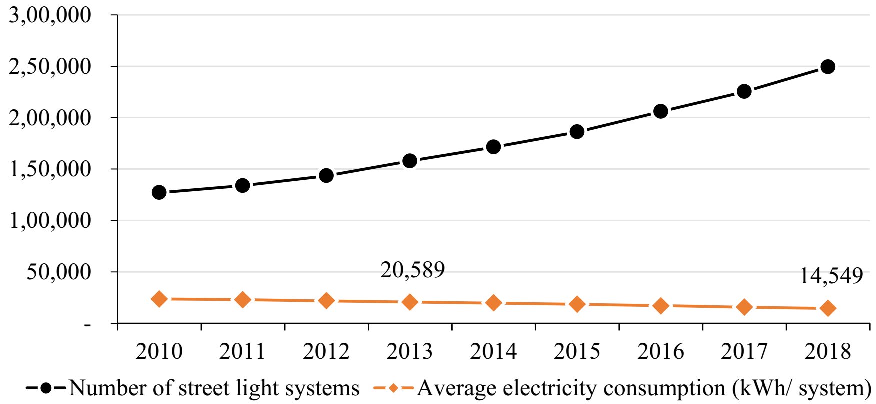


Fig. 11.4 Number of street lighting systems and average electricity consumption. *Source* PLN (2019)

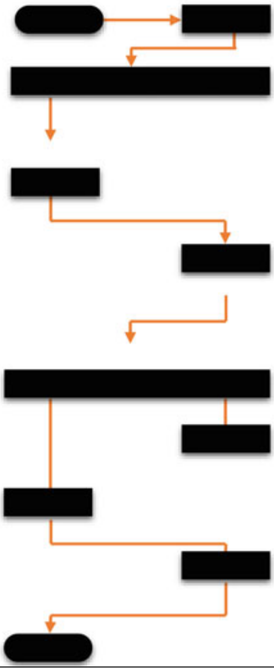
to support the ESCO scheme for energy conservation in public sectors (MDA 2017). The letter aims to resolve the allegation by the Supreme Audit Agency, or Badan Pemeriksa Keuangan (BPK), who views the payment of shared savings as an installment of a loan of energy efficiency investments while the local government is prohibited to have a loan from a private company (Al Irsyad and Nepal 2016). Similar problems have hampered European Union countries (Bertoldi and Boza-Kiss 2017). Besides, BPK questioned the ESCO selection process and the calculation of the percentage of savings shared between the ESCO and the local government. The problems were caused by the lack of ESCO regulations in the public sector. Regulation of public–private partnerships (PPP) is available, but is designed for infrastructure projects generating revenues and not for reducing costs in public services.

The Circular Letter is a modification of the PPP regulation. The purposes of the letter were to ensure energy efficiency sustainability and to optimize the value-added to the local government budget by implementing a performance-based budget. Local governments could then cooperate with an individual or a company holding intellectual property rights on energy efficiency. The process of cooperation is shown in Table 11.2. At first, an ESCO submits a proposal offering energy conservation services to the local government. The government must respond to the proposal within 30 days. Once local government agrees with the proposal, both parties sign a letter of intent (LOI) and a memorandum of understanding (MOU).

In the next stage, the ESCO conducts an energy audit to analyze energy efficiency potential and reports the results within 90 days after the signing of the letter of intent and the MOU. The local government uses the report as a basis for making the terms of reference of ESCO procurement. The procurement process of ESCO services should be completed within 30 days. The local government can directly select the ESCO if only one ESCO applies; otherwise, the selection should consider the previous experience in another three municipalities, higher economic benefits,

Table 11.2 Flowchart of the cooperation process of an ESCO with the public sector

No.	Activities	ESCO	Municipality	Days to Due
1	Proposal submission			
2	Letter of Intent (LOI) and Memorandum of Understanding			30
3	Identification and analysis of energy efficiency potentials			90
4	Procurement process of ESCO services			30
5	Contract signatory			30
6	Budget preparation			
7	Designs and constructions			365
8	Performance evaluation			90
9	Payment of ESCO services			*



* Up to 3 years

ESCO energy service company. *Source* MDA (2017)

and the proposal's originality. The energy saving performance contract (ESPC) should be signed within 30 days after the procurement process ends. The maximum term of the ESPC is 3 years.

Following the ESPC signing, the local government should prepare the budget for ESCO services. The budget is allocated from energy cost savings and additional funds required to pay all energy efficiency service costs within 3 years, which is the maximum payment period. The Circular Letter emphasizes that the budget is not for paying the energy efficiency investment but instead the energy efficiency services. The directive is to underline that the payment is not a loan installment of energy efficiency investment; for that, the local government should allocate the budget on a special expenses account for third party services. The budget should be approved by the regional House of Representatives. On the other side, the ESCO should complete the energy efficiency measures within a year. Subsequently, the energy efficiency performance will be evaluated for three months before the local government pays the energy cost saving share to the ESCO.

Since its launch in 2017, the Circular Letter has not yet been used for energy conservation projects in municipalities. Based on interviews with staff of the

Ministry of Domestic Affairs and the Agency of National Development Planning (BAPPENAS), several projects based on the Circular Letter are still in the planning stages. Several municipalities have difficulties obtaining budget approvals from the regional House of Representatives. One of the questions raised by the House is whether the ESCO scheme is like a double payment to both PLN and the ESCO.

11.4 ESCO Case Study in Indonesia

Beyond the concern of the House of Representatives, there are several other questions concerning the efficiency of the Circular Letter. First of all, the Circular Letter sets the criteria of the ESCO to have intellectual property rights to energy conservation measures (MDA 2017). Al Irsyad and Nepal (2016) argued that energy conservation measures for public infrastructure such as streetlights are common and easily adapted to other locations without the need for specific and detailed energy audits. Those measures, in sequence, are installing power meters on unmetered streetlights, using LED lamps or other high-efficiency lamps, and applying dimming features in smart street lighting technology. The first measure may need to be the rewiring of streetlights to give them a balanced load in a three-phase system as one of PLN's requirements. The measure may only require a small investment amount but can save 50% in electricity bills since unmetered streetlights are charged at a fixed (and twice higher) tariff than the normal tariff (Al Irsyad and Nepal 2016). Therefore, the Circular Letter requirement to have intellectual property rights is unnecessary and may lead to an inefficient monopoly market. As a substitute, the MEMR could introduce an ESCO certification program to ensure the credibility of the ESCO. While avoiding a monopoly market, the municipality should also consider the economic scale of an ESCO's services. An ESCO has fixed investments, such as operational vehicles, an office, and its equipment, regardless of the number of streetlights managed.

The second issue is that giving priority to an ESCO with experience in three other cities may also lead to a monopoly market discussed above. The provision is designed to obtain an experienced ESCO that increases the confidence and security of municipalities when implementing the Circular Letter. However, on the other end, the regulation gives less opportunity to new ESCOs which may have new and more effective measures. The Ministry of Domestic Affairs would do better to change the provision to apply the Indonesia National Standard (SNI) for the bidding ESCO. The relevant standards are SNI ISO 50001:2012 for energy management and SNI ISO 50002:2014 for energy audits. These standards have been implemented as Indonesian National Work Competency Standards to assure the competency of energy auditors and energy managers in Indonesia. Moreover, the Circular Letter also does not mention who will do the verification of actual energy savings as a provision for ESCO payment. Municipalities mostly do not have capable personnel and, therefore, municipalities should appoint a company holding SNI ISO 50015:2014 for the calculation and verification of energy performance.

Hopefully, using these SNIs would convince the regional House of Representatives as well as minimize legal auditing issues by the BPK.

Other priority criteria are ascribed to ESCOs offering higher economic benefits and proposal originality. However, the MDA (2017) does not regulate directly how to determine the economic benefits and proposal originality, potentially causing new disputes between municipalities, ESCOs, and BPK. Higher economic benefits may require higher costs: i.e., a higher saving share. In the end, the BPK may raise questions if the appointed ESCO proposes the highest cost to obtain the highest economic benefit. Table 11.3 illustrates how different evaluations of economic benefit will produce different results. In Table 11.3, three ESCOs bid on a project by offering different energy-saving targets and saving shares. If the evaluation is based on the lowest ESCO cost, then ESCO 1 will win the bid since ESCO 1 only asks for the lowest saving share, equivalent to 144 megawatt hours (MWh), to reduce energy consumption by 1,440 MWh. In contrast, ESCO 3 offers the highest energy savings of 2,880 MWh but, consequently, demands the highest saving share of 1,152 MWh during a 3-year contract period. ESCO 2 offers neither the highest savings nor the lowest saving share; however, eventually, ESCO 2 provides the lowest cost and benefit ratio (CBR). Cost is defined as the sum of saving payments to the ESCO bills while the benefit is defined as the net electricity saving for the municipality.

Selecting the ESCO offering the lowest CBR is more appropriate than only considering the lowest cost or the highest benefit; however, another consideration is the lifespan of used energy efficiency technologies. An ESCO may argue that the benefits of their investment could last longer than 3 years—the maximum contract period—and, consequently, the benefit will be higher than the costs; however, such an argument seems unreliable, at least in developing countries. For instance, the MEMR deployed pilot projects of smart street lighting systems in seven cities in

Table 11.3 Illustration of ESCO bidding evaluation

No	Description	ESCO I	ESCO II	ESCO III
A	Original electricity consumption (MWh/month)	100	100	100
B	Targeted new electricity consumption (MWh/month)	60	40	20
C	Targeted electricity saving (MWh/month) = A−B	40	60	80
D	Contract period (years)	3	3	3
E	Saving during contract period (MWh) = C * 12 * D	1,440	2,160	2,880
F	Saving share bidding in year 1 (%)	10	15	40
G	Saving share bidding in year 2 (%)	10	5	40
H	Saving share bidding in year 3 (%)	10	5	40
I	Saving for ESCO during contract period (MWh) = (F + G + H) * C * 12	144	180	1,152
J	Net saving for municipality (MWh) = E−I	1,296	1,980	1,728
K	Cost and benefit ratio (CBR) = I/J	0.11	0.09	0.67

MWh megawatt hour. *Source* Own calculation

2013 but, at the moment, the smart dimming feature is no longer used due to a lack of maintenance ability in the municipalities (Al Irsyad et al. 2019). The contract period should be extended to more than 3 years to obtain lower CBR and assure the sustainability of energy efficiency measures. The benefits could be defined more broadly to include smart services improving quality services for urban populations, such as smart traffic signage, improved pedestrian safety, and environmental monitoring and warning systems (Jin et al. 2016; Eakambaram 2017; Griffiths 2017). In this case, the MEMR should provide a standard contract including measuring and verification methods that can become a reference for ESCO projects across all municipalities.

The municipality should also see the streetlights as income-generating units instead of cost units (Al Irsyad et al. 2019). Currently, the municipality has gained the streetlight tax collected by PLN from the electricity customers. In the future, with the help of smart street lighting technology, streetlight poles can be used for digital signage showing public information and advertising content that can be adjusted to the people passing by. The network of streetlights could also be rented as a network for small cells of mobile traffic data (Griffiths 2017). To gain these income-generating activities, the municipality could select a specific ESCO by using the conventional PPP regulation. In addition to the partnership, the ESCO may have an obligation to invest in energy efficiency measures.

11.5 Policy Recommendations

11.5.1 Auction Mechanism Improvements

The auction mechanism for energy efficiency or demand reduction is a relatively new concept that did not exist one decade ago (Rosenow et al. 2017). In the auction mechanism, financing is first received from either an energy-saving fund, a levy on energy bills, capacity charges, or another form of budget allocation. After this stage, the market actors are allowed to put forward bids, either in competitive tenders where the lowest bid wins or within a framework setting the price per unit of energy-saving, inviting proposals to deliver savings at that price. In other words, the mechanism aims to achieve energy-savings at highly attractive prices whilst avoiding deadweight effects associated with financial support. Our literature counted six auction mechanisms—two in the United States and one each in Switzerland, Portugal, the United Kingdom, and Germany (Rosenow et al. 2017). Such auction mechanisms can take on a variety of forms and designs.

Auction mechanisms help to drive energy efficiency in the following ways:

- Deliver cost-efficient energy-saving projects (i.e., minimum requested budget for the highest possible energy savings). In general, selected parties (primarily energy service companies, contractors, technology providers, energy agencies, engineering firms, and municipal utility companies) are invited to submit bids for the planning and implementation of energy efficiency projects (Radgen et al. 2016). Parties who are interested can submit offers for an energy savings amount and put in a bid for a required budget, which forms 20% to 40% of the total costs, including costs for information, planning, conceptual design, investment, measurement, verification, etc. Hence, bidders do not submit the maximum price limit set by the government per se but are closer to the actual value of needed subsidies. Winners are chosen based on the ratio between the requested budget and the energy savings offered to achieve the minimum requested budget for the highest possible energy savings. In other words, by design, the auction mechanism draws out the most cost-effective enhancements from among all the contenders through the use of a specific price in selecting the winner of the auction.

- Engage and encourage a top-down push for energy efficiency projects since they are voluntary measures, so no party will be obliged to establish a business case in which they are not interested. Auction mechanisms are effective in engaging and encouraging a top-down push for energy efficiency projects, which would otherwise not pay for themselves through energy savings made (e.g., infrastructure with a payback period more than 8 years). This is also attributed to the fact that program tenders, in comparison to white certificates, are voluntary measures and might, therefore, be more likely to find political acceptance.

Allow for the aggregation and bundling of energy-saving projects, facilitating larger savings potential and economies of scale. Often, tenders are issued for both projects and programs (IPEEC 2016). Projects are dedicated to individual companies in the industrial and service sector who would like to implement energy-saving measures within their company. On the other hand, programs are bids submitted by associations or other operating agents that bundle multiple similar projects into one program. Both open and closed (i.e., sector-specific) tenders are available for programs. In the case of Switzerland's ProKilowatt, auctions are held independently for programs and projects to avoid competition between the two types in the same auction. Through program tenders, similar individual projects (across one technological category and one region) can be aggregated and bundled, allowing larger savings potential and achieving economies of scale to be tapped into.

Provide flexibility for bidders to select their technologies and programs for implementation in open tenders. Some auction mechanisms offer both open and closed tenders (IPEEC 2016); this is demonstrated in German auctions featuring both an "open" auction slot that is technology- and sector-neutral, and a "closed" auction slot which is sector-, beneficiary- or technology-specific. Open tenders ensure flexibility as bidders are allowed to select their technologies and programs for implementation. On the other hand, closed tenders help to address specific themes with known large potential and constraints, or innovation potential.

11.5.2 Design a Super ESCO to Strengthen the Financial and Technical Capacity of Private ESCOs

Super ESCOs have proven to be a success across the jurisdictions where they are implemented, bringing about large energy savings, fostering the ESCO industry in terms of technical and financial capabilities, as well as aiding small and medium-sized enterprises (SMEs) in taking up energy efficiency projects. Most importantly, the credit-worthy super ESCOs can back the ESCOs in issuing guaranteed energy savings contracts under EPCs, helping energy efficiency projects to secure bank loans. To date, at least eight super ESCOs have been implemented across the world: FEDESCO in Belgium, EC2 in the Philippines, Tarshid in Saudi Arabia, Etihad ESCO in the United Arab Emirates, HEP ESCO in Croatia, the R2E2 Fund in Armenia, EESL in India, and the Fakai Scientific Services Corporation in the PRC.

A super ESCO will support the public sector to enter an EPC scheme and guarantee specific energy savings, notably for buildings or street lighting over a set period, either in monetary terms or as a savings percentage. A super ESCO will facilitate project aggregation to make energy efficiency financing more attractive, procure large volumes of energy-efficient devices and equipment and, consequently, bring about a rapid reduction in prices, making the energy efficiency measures more cost efficient. This result can have significant advantages for governments, reducing energy bills of public facilities, supporting the fiscal sustainability of governments' energy efficiency efforts, requiring less enforcement than regulation, and according to the market the flexibility to select the most cost-efficient technologies.

Besides, a super ESCO can put in place all required procedures, templates, and documents to enable the maturity of the domestic EPC market. Project development and implementation can be subcontracted to private ESCOs on a competitive tendering basis. Local ESCOs will build their capacity to develop and offer EPC with low-risk projects while receiving support from the super ESCO to gain much-needed skills. Later, these ESCOs could extend their services to the commercial and industrial sectors to drive more rapid transformation of energy efficiency.

In Indonesia, we recommend the central government to consider two institutional options to ensure that the super ESCO, if desirable, can help tap the public sector's energy efficiency potential and facilitate the domestic energy services and private sector ESCOs. The first option is to leverage existing government agencies with an energy efficiency mandate to set up a super ESCO. The other option is to leverage the power utility companies to create a utility-based super ESCO.

There could be a potential conflict of interest between the state-owned super ESCO acting as an ESCO for public sector energy efficiency projects and the emerging commercial ESCOs who need public sector projects to support their growth and development (Limaye and Limaye 2011). Within the private sector, a super ESCO itself has the capacity to develop and implement projects. Nonetheless, this issue can be overcome by having the government dedicate specific responsibilities to the super ESCO to engage the private sector ESCOs as implementing agents.

In the long run, the super ESCO should be aimed at building the capacity of local private sector ESCOs and creating a competitive private market for ESCO services. Hence, the super ESCO is best suited to take up the role of a capacity builder by engaging private ESCOs as contractors for parts of the implementation, such as installation, commissioning and performance-monitoring, etc. The super ESCO can also help to arrange access to guaranteeing/de-risking financing for small private ESCOs to support them in implementing projects and building their capacity and credentials.

Precisely, a super ESCO helps to overcome the challenges faced by SMEs in Indonesia's energy efficiency market as it can:

- Facilitate energy efficiency project aggregation to make energy efficiency projects of SMEs more attractive for financing. The government could emulate India's energy efficiency services limited (EESL) in terms of aggregating large demands for energy-efficient equipment and procuring large volumes from a variety of suppliers that meet strong technical standards (Sarkar and Moin 2018). This helps to establish a demanding market for participating manufacturers and, as a result, brings about a rapid reduction in prices, making the energy efficiency measures more financially attractive (cost efficient).
- Provide SMEs with up-front financing. The government could also learn from the Energy Saving Association of Armenia's R2E2 Fund, under which an SME pays the fund its baseline energy costs over a contract period. The fund then designs the project, hires subcontractors, oversees construction and commissioning, and monitors the subproject (Sarkar and Moin 2018). In this case, SMEs will incur no debt; the fund directly pays the energy bills to the utility company on the SMEs' behalf, retaining the balance to cover its investment cost and service fee. In other words, project aggregation, up-front financing and the Energy Saving Association are critical to overcoming the lack of financial capacity among SMEs to build up their energy efficiency.

11.6 Conclusion

Global electricity demand is growing at a rapid pace, especially in developing countries. One potential for energy efficiency is in the electricity used by streetlights. Energy efficiency measures in streetlights are simple and common so the measures can be immediately implemented to all streetlights without conducting detailed and expensive energy audits. Nevertheless, municipalities usually have budget limitations so an ESCO is one of the possible solutions to finance energy efficiency in streetlights. However, ESCOs in public sectors are uncommon in developing countries like Indonesia. The Supreme Audit Agency (BPK) had accused the ESCO scheme of being a loan to municipalities who are prohibited from receiving loans from the private sector. The BPK also questioned the method to determine the saving share given to the ESCO. Based on those problems, the Minister of Domestic Affairs released a Circular Letter to solve those legal issues hampering energy efficiency in the public sector. The main feature of the Circular Letter was to emphasize that paying the ESCO is not a loan of investment but instead a payment for an energy efficiency service during the ESCO contract period. Nevertheless, since its release in 2017, the implementation of the Circular Letter has not been well accepted. No ESCO project has been implemented yet under the Circular Letter. Some projects are under preparation, while others had been turned down by the regional House of Representatives who views the ESCO contract as an additional expense to current electricity bills for streetlights.

Our study proposes several improvements to the Circular Letter. Firstly, the Circular Letter should not limit the ESCO to have intellectual property rights since this may lead to an inefficient or monopoly market. For the same reasons, the Ministry of Domestic Affairs should not prioritize ESCOs with experiences in three other cities. ESCOs are a new business type in Indonesia and as new companies emerge, they should be given equal opportunity. The experience requirement is also unnecessary since the nature of the business is that all investment and technical risks will be burdened by the ESCO; therefore, the municipalities should be indifferent to using experienced or inexperienced ESCOs. The third proposal is to use the lowest cost–benefit ratio to determine the best economic benefits. The current maximum contract period (i.e., 3 years) is too short to determine actual benefits and so our fourth proposal is to extend the period by also considering additional features of smart services that can be provided by streetlights managed by an ESCO. We also propose a new business scheme to convert streetlights from cost units into revenue-generating units, for example, as smart digital advertising and mobile traffic data network devices.

Furthermore, we recommend Indonesia's government to consider the energy efficiency auction mechanism to channel the public budget into energy efficiency investments. The mechanism is a cost-effective method of competitively selecting the market proposals that result in the highest cost savings of public funding. Last, but not least, we recommend Indonesia's government to consider the option of the super ESCO to tap the public sector's energy efficiency potential and facilitate the domestic energy services and private sector ESCOs. The rationale for this super ESCO must be first understood, in the sense that it will develop, finance and implement energy efficiency projects on a commercial, for-profit basis, using local ESCOs as key delivery partners.

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Chapter 12
The Viability of Green Bonds as a Financing Mechanism for Energy-Efficient Green Buildings in ASEAN: Lessons from Malaysia and Singapore

Anant Kapoor, En-Qi Teo, Dina Azhgaliyeva, and Yang Liu

Abstract As the growth of energy demand outstrips that of energy supply in Southeast Asia, it is imperative for the Association of Southeast Asian Nations (ASEAN) member states to seek energy efficiency improvements for sustained energy security. While green buildings have an overall low penetration rate in ASEAN compared to the rest of the world, a relatively large proportion of green bond proceeds in ASEAN have been channeled to financing green buildings. Green bonds hold vast potential as a financing mechanism, and the importance of green bonds as a funding source for green buildings in ASEAN is projected to increase in the future. ASEAN member state governments can encourage the use of this source of finance to address under-investment in green buildings by providing information on raising funds through green bonds, endorsing investment in green buildings through codifying green building standards, and promoting local currency bond financing through domestic investors.

Keywords Green buildings · Green bonds · Energy efficiency · ASEAN · Green *sukuk* · ICMA green bond principles · ASEAN green bond standards · Sustainable finance

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12.1 Introduction

The building sector represents about 30% of global final energy use and its energy savings potential is massive. However, total spending on energy efficiency in the global building sector represented less than 9% of $4.6 trillion spent on construction and renovation in 2016 (IEA 2017b). Between 2015 and 2018, technical efficiency gains only avoided energy use equivalent to 0.7% of residential building final energy demand, while structural factors, such as increasing building floor area and adoption of appliances such as air conditioning, created additional energy demand equivalent to over 2% of final demand (IEA 2019a). Hence, it is essential to leverage innovative financing, technology, and policy tools to accelerate transformation of buildings and construction across the world. Green buildings, which are buildings that, in their design, construction or operation, reduce or eliminate negative environmental impacts, are a potential solution as they generate benefits to the climate and natural environment (World Green Building Council n.d.).

The Association of Southeast Asian Nations (ASEAN) has established collective targets of a 20% decrease in energy intensity (EI) by 2020 and a 30% decrease in EI by 2025, relative to the base year of 2005. As ASEAN countries experience a surge in energy demand driven by their growing populations, fast growing economies and improved living standards, controlling energy consumption through energy efficiency measures is a cost-effective option compared with heavy investments in energy infrastructure (ADB 2013). Considering the massive demand of new floor area in the emerging economies, construction of green buildings and deep energy renovations of existing buildings could save around 330 exajoules in cumulative energy savings till 2060, more than all the final energy consumed by the Group of 20 (G20) countries in 2015 (IEA 2017a).

Despite such government efforts, in many ASEAN countries, there has not yet been sufficient penetration of green buildings (Baker 2019). Meanwhile, the green bond market is emerging in ASEAN as an important source of financing for projects or assets with positive environmental or climate change mitigation benefits. Green bonds differ from conventional bonds because their proceeds are devoted to environmentally beneficial investments with specific impact achieved for a given period of time (ADB 2018). In the ASEAN green bond market, green buildings are one of the main projects green bonds are issued to fund.

Can green bonds be a mechanism through which investment in green buildings in ASEAN can be increased? In this chapter, we first discuss the current incentives for investment in green buildings and the reasons why investment in green buildings has remained lackluster despite these incentives. We then examine the outlook on green bonds in ASEAN and the potential of green bonds as a main source of funds for green building projects, finding that green bonds are a suitable funding source for green buildings in ASEAN. Thereafter, we turn to look at the challenges that may present themselves in using green bonds to finance green building projects. Finally, we conclude with a discussion on recommendations for the future.

This discussion on the feasibility of green bonds as a financing instrument for green buildings in ASEAN presented in this chapter provides insights that may be applicable to research on green financing solutions, as well as to policies to incentivize private investment in energy efficiency in ASEAN. Following the research on barriers to the adoption of green bonds conducted by Azhgaliyeva et al. (2020), this chapter's main contributions to the literature on green financing in ASEAN are a comprehensive exploration of the various obstacles to investment in green buildings in ASEAN, and an analysis of how the financial instrument of green bonds could provide an attractive opportunity for green building developers to raise external capital, incentivizing further investment in green buildings. Drawing from case studies of green buildings financed by green bond issuance in Malaysia and Singapore, we find that transparency in building energy reporting is a crucial factor for success in raising capital through green bonds. We make three major policy recommendations to increase the adoption of green bonds for green building investment. Governments should increase information provision on the process of green bond issuance, endorse green building codes to increase transparency in reporting energy improvements, and promote local currency bond financing through domestic institutional investors.

12.2 Outlook on Investment in Green Buildings in ASEAN

While there are various benefits to investing in green buildings, these benefits do not seem to be fully appreciated and thus internalized by the market. In both developed and developing economies, energy efficiency investments in buildings are often considered a risk. Financial incentives, including conventional loan and debt finance and innovative green bonds, must be put in place to encourage the take-up of energy efficient technologies and reward energy conservation practice. This section explores the current incentives for investment in green buildings, as well as the reasons why the market is not sufficiently moved by these incentives to realize the full benefits of green buildings through investing at the appropriate level.

12.2.1 Incentives to Invest in Green Buildings

Government Initiatives to Encourage Green Buildings

Across the world, there is still a lack of policy to drive energy efficiency investments in buildings. As of 2016, nearly 70% of final energy use in buildings globally was not covered by mandatory codes and standards, and currently two-thirds of countries still do not have comprehensive building energy codes to cover new buildings construction (IEA 2017b).

Increasingly, ASEAN governments are implementing policies to mandate, and are providing incentives to encourage green developments in the built environment. The Brunei Darussalam government implemented the Energy Efficiency and Conservation (EEC) Building Guidelines for the Nonresidential Sector in 2015, which mandates that the Energy Efficiency Index (EEI) for government buildings is set at 175 kilowatt hours per square meter (kWh/m^2) (Thambipillai and Pang 2019). In Cambodia, the National Policy, Strategy, and Action Plan on Energy Efficiency, established in 2013, encourages adherence to newly designed green construction guidelines (Asia Pacific Energy 2013).

In Jakarta, Indonesia, most new Grade A office buildings will have to achieve GREENSHIP certification. GREENSHIP is a local green rating tool for buildings (Noonan 2018). Indonesia's Minister of Public Works and Housing Regulation No. 2 of 2015 also contains compulsory, voluntary, and recommended actions for energy efficiency improvements. To encourage green buildings, Malaysia has also adopted various rating tools, such as the Green Building Index (GBI) in 2009, and the Green Performance Assessment System in Construction (Green PASS) for government buildings in 2012 (Hamid et al. 2014). The Malaysian government additionally provides incentives—mostly in the form of tax breaks—to developers for buildings that meet the criteria to be certified under the GBI (Aliagha et al. 2013).

The Philippines, Singapore, Thailand, and Viet Nam have also adapted building energy performance measurement tools to their contexts, and respectively use the Building for Ecologically Responsive Design Excellence (Culiao et al. 2018), the Building and Construction Authority (BCA) Green Mark scheme (Building and Construction Authority n.d.), Thailand's Rating of Energy and Environmental Sustainability (Thanakan and Inkarojrit 2018), and the LOTUS (Nguyen and Gray 2016). In particular, Singapore's BCA Green Mark Scheme is internationally recognized, used in many countries in ASEAN, and associated with a sale premium for certified buildings in Singapore (Poe 2017).

Economic Benefits of Investment in Green Buildings

Furthermore, green buildings are a lucrative investment (Eichholtz et al. 2013). In ASEAN too, green buildings appear to be a gainful investment. Empirical evidence suggests that there are cost savings associated with green buildings in Malaysia (Dwaikat and Ali 2018). In the Singapore context, green buildings yield higher returns on investment than their counterparts (Addae-Dapaah and Chieh 2011; Deng and Wu 2014; Heinzle et al. 2013; Ho et al. 2013). Residential buildings that have achieved green certification also command a premium in the housing market (Fesselmeyer 2018). This is consistent with trends in other countries, where occupants also prefer green buildings, as revealed by a higher willingness-to-pay (Robinson et al. 2016).

Despite the multiplicity of benefits that accrue from green buildings, there has been chronic under-investment in green buildings in Southeast Asian cities, in which the green building penetration rate, like most other Asian cities, is lower than the global average (Hill 2017). The perception of high up-front costs, a mismatch between the life of the asset and its holding period in a portfolio, and misplaced incentives of market participants have adversely affected investment in green buildings.

12.2.2 Reasons for Under-Investment in Green Buildings in ASEAN

In this section, we cover four reasons for under-investment in green buildings specifically, before discussing three additional reasons for under-investment in energy efficiency in general.

One of the main overarching reasons for a lack of investment in green buildings is the split incentives in the buildings market. While owners and occupants enjoy the cost savings associated with improved energy performance, developers have to bear the upfront costs of construction. Among developers, there exists a perception that the construction of green buildings would involve large upfront costs (Hiltz 2010).

Another reason for inadequate investment in green buildings is that incentives and benefits are structured to discourage such investment for market participants such as developers, bankers and building owners. Developers are hesitant to absorb the additional upfront costs of green building design when the cost savings will only accrue to the owners (Deng and Wu 2014). Bankers are reluctant to release funds for additional capital costs, as they wish to avoid the increase in nonpayment risk by minimizing the capital investments. Furthermore, these market participants are unwilling to put in place systems to validate savings that result from energy efficient equipment. Energy savings can only be visible with ex post assessment, and thus will not be fully materialized in the event that the green building pipeline is inadequately designed. The market value of these savings is also subject to energy prices uncertainty. Hence, owners are deterred from investment due to uncertain savings from utilities, ambiguous long-term gains, and a focus on the immediate affordability of the building (IFC 2019).

A third reason for the funding gap for green buildings is that there is a mismatch between the longevity of buildings, and the relatively short holding periods for real estate assets in investment portfolios. For instance, while the lifespan of a building is 70 to 100 years, financiers hold real estate assets mostly for 7 to 10 years while building owners hold them for 10 to 15 years. There is also a mismatch between these asset holding periods and when the building's lifespan might be disrupted by climate change and/or forced compliance with harsher regulations. Hence, market participants may not be incentivized to invest in green construction, since the costs to environmentally unsustainable construction and, on the flip side, the benefits to green buildings, cannot fully materialize while the market participants are in possession of the asset (IFC 2019).

Finally, landlords have minimal incentives to make an investment in energy efficient equipment as long as the tenants pay the utility bill. Unless there is strong interest in reducing operational and maintenance costs among tenants, landlords will remain unwilling to switch to more energy-efficient appliances. In Singapore, this problem was particularly pronounced as the split incentives ended up providing hardly enough motivation to switch to energy-efficient technologies (ACE 2019). On the other hand, for commercial tenants, energy costs are evaluated solely as a function of the space occupied rather than an account of the total energy used, again leaving tenants with no incentive to lobby for more energy-efficient technologies since there are no potential cost savings to be reaped (UN ESCAP 2012).

For the above reasons, the market for green construction has punched below its weight, despite comprehensive policies to aid green building construction in many jurisdictions. This is also correlated with weak enforcement regimes, a lack of information provision, and a lack of technical capacity. Furthermore, the green building industry, being a subset of the energy efficiency space, further faces issues that are endemic in the energy efficiency market.

A lack of information about energy efficiency equipment and technologies results in financial institutions such as banks assessing their risk as too high, which leads to higher interest rates on loans (ACE 2019). The small size of energy efficiency projects also deters investors from financing such projects (ACE 2019). In the event that small energy efficiency projects cannot be bundled together to temper transaction costs, each of these small projects will remain unfinanced (Taylor et al. 2008). A final important barrier to investment in energy efficiency, including green buildings is distorted energy prices and unfavorable tax regimes. The biggest damage arguably has been done by energy subsidies from various governments around the world, as these disincentivize the conservation of energy (UNEP 2008).

In conclusion of this section, the combination of factors such as a lack of information about energy efficiency equipment, the small size of energy efficiency projects, and distorted energy prices are responsible for underinvestment in energy efficient technologies. For green buildings specifically, factors such as perception of high up-front costs, mismatch between life of the asset and its holding period in a portfolio, and structural incentives that incline market participants against investment in energy efficiency technology have precluded an expansion in investment.

12.3 Issuance of Green Bonds to Fund Energy-Efficient Buildings

Green bonds may potentially be an important financing mechanism to encourage sustainability in the built environment. Globally, demand for green bonds is high due to an increasing emphasis on impact investing (Castillejos-Petalcorin et al. 2018), and green bonds may be especially important as a tool to raise funds for environmental sustainability-related projects in developing countries (Banga 2019).

The following section will provide an overview of the landscape of green bonds in ASEAN and beyond.

12.3.1 Suitability of Green Bonds for Financing Energy Efficiency Projects

Proceeds from green bond can be utilized to fund or refinance improvements in energy efficiency in new and refurbished buildings, district heating, smart grids, energy storage, appliances, and products. Green buildings address considerations such as waste management and water usage and include energy efficiency improvements to meet regional, national, or internationally recognized certifications or standards (Azhgaliyeva et al. 2020).

Presently, in cases where external finance is solicited, energy efficiency projects are typically financed by bank loans. But bank loans have proven to be an inadequate source of funds. Among alternative sources of finance for energy efficiency projects, energy performance contracts (EPC) are also frequently employed. In EPCs, energy service companies (ESCOs) repay loans from project profits. Another source of funding are green banks, which invest a combination of private and public funds in energy efficiency projects. Green bonds, which are a debt instrument created exclusively to raise capital for environmentally friendly businesses or activities, also hold massive potential: the value of green bonds for energy efficiency grew from $16 billion in 2016 to $47 billion in 2017 (IEA 2018). While year-on-year issuance in 2018 contracted by 8% to approximately $45 billion, but issuance was still markedly higher than $3.8 billion in 2014, indicating that green bonds with an efficiency component have gained traction in financial markets (Climate Bonds Initiative 2019a).

However, unlike other financial instruments, green bonds permit borrowers to attract ethical investors, to promote their reputation and to claim sustainability (Azhgaliyeva et al. 2020). An IEA (2018) report noted that a majority of investments in energy efficiency are self-financed. However, in certain situations, external financing may be imperative to encourage owners to make upgrades to infrastructure to improve energy efficiency (USAID 2018). For entities that wish to finance energy efficiency projects, green bonds enable access to capital at lower cost and with fewer restrictive covenants than bank loans, and are hence an attractive source of funds (Azhgaliyeva et al. 2020).

12.3.2 Landscape of Green Bonds in ASEAN

The global market for green bonds has also grown strongly since the first green bond was issued just over a decade ago. By November 2018, cumulative bond issuance had exceeded $500 billion. Although this growth is encouraging, it is important to put it in perspective. In 2018, the global bond market was worth roughly $100 trillion (BIS 2019). Green bonds represent only 0.5% of the total, and green bonds for energy efficiency accounted for a mere 0.05% of global debt security issuance in 2018 (IEA 2019b).

There were 406 green bonds issued from 2016 to date as recorded in the Climate Bonds Initiative database. Indonesia and Malaysia each issued three green bonds, and the Philippines and Singapore each issued four green bonds. The number of green bonds issued in ASEAN remains relatively small compared to the People's Republic of China (19), France (34), Germany (21), Japan (61), the Netherlands (19), Sweden (44), and the United States (49).

However, there is strong institutional support for green bonds as a means for financing by the Indonesia, Singapore, and Malaysia governments. In Indonesia, green bonds are issued by the government, while in Singapore and Malaysia, the issuance of green bonds is supported by green bond grants that cover the cost of labeling bonds "green" (Azhgaliyeva et al. 2019, 2020; Azhgaliyeva and Liddle 2020). Indonesia issued nearly half (49%) of green bonds in ASEAN (Fig. 12.2), coming in as the largest issuer of green bonds in ASEAN over the period 2017–2019, followed by Singapore (19%) and Malaysia (15%). Issuance of green bonds in ASEAN is growing fast. It increased by half in 2018 and nearly doubled in 2019 comparing to 2017 (Fig. 12.3). Nevertheless, ASEAN issued only around 1–2% of annual global green bonds (Fig. 12.1).

There are also special forms of green bonds, such as green *sukuk,* that have been introduced in the market. Green *sukuk*, which are green Islamic financial certificates

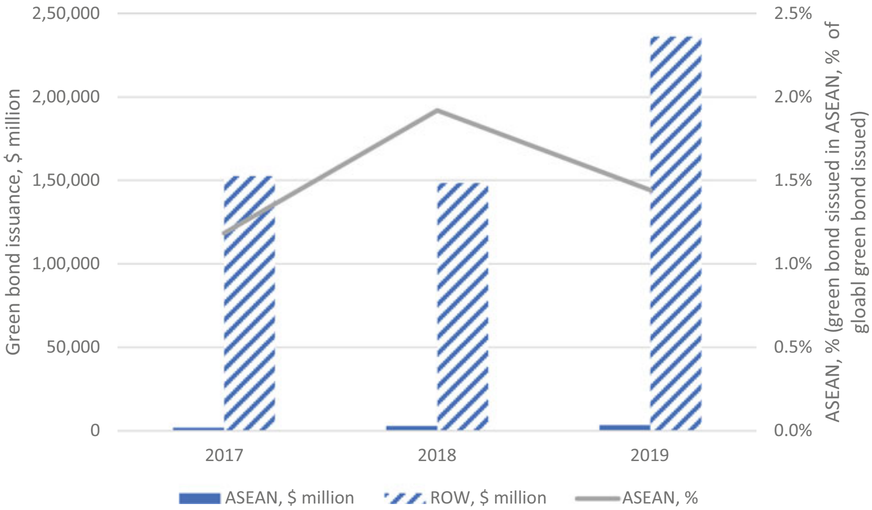

Fig. 12.1 Amount in green bond issuance in ASEAN relative to rest of world (ROW). *ASEAN* Association of Southeast Asian Nations. *Source* Authors' own using data from Bloomberg

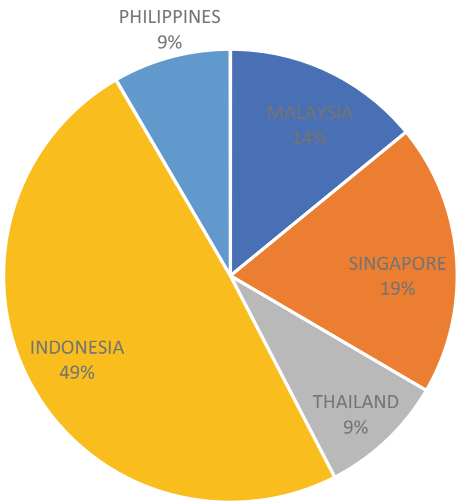

Fig. 12.2 Issuance of green bonds in ASEAN by country (2017–2019). *ASEAN* Association of Southeast Asian Nations. *Source* Authors' own using data from Bloomberg

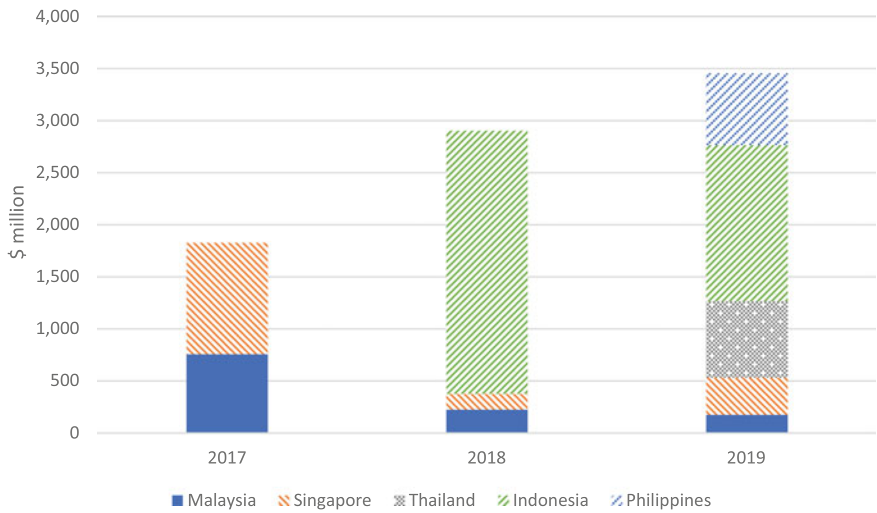

Fig. 12.3 Issuance of green bonds in ASEAN, 2017, 2018, 2019. *ASEAN* Association of Southeast Asian Nations. *Source* Authors' own using data from Bloomberg

that function the same way as green bonds, are gaining popularity in Indonesia and Malaysia (Climate Bonds Initiative 2019b). Green *sukuk* allow issuers to tap into the burgeoning Islamic finance market, and the objective of such instruments is aligned with the Islamic tenet of environmental protection (Alam et al. 2016; Muhmad and Muhmad 2018).

Sukuk are financial instruments intended to be complaint with sharia law, which are the rules that define Islamic doctrine. Even though *sukuk* are frequently referred to as “sharia-compliant bonds,” they are in fact structured as equity-based instruments and indicate the ownership of an asset. Riskless return or fixed income is not sharia compliant. When an investment is made in a *sukuk*, an investor obtains a certificate from the issuer who uses the proceeds to purchase an asset (Impactivate 2020). Rather than earning interest, the investor who had purchased the *sukuk* earns a share of the profits. Since *sukuk* indicate asset ownership, they are priced based on the value of the assets backing them. Bonds, however, are priced based on credit rating (Islamic Finance Foundation 2014).

While *sukuk* are sharia compliant securities backed by a specific pool of assets, green *sukuk* are sharia compliant investments in renewable energy, energy efficiency, and other environmental assets. Green *sukuk* address the sharia concern for protecting the environment and are an alternative to green bonds because, as interest bearing instruments, green bonds may preclude investors who adhere to principles of Islamic finance (Pew Research Centre 2017).

To catalyze the market for green *sukuk* issuances, Malaysia instituted the Green SRI *Sukuk* Scheme including incentives such as tax exemptions for recipients from year of assessment 2018 to 2020, a green *sukuk* grant scheme to compensate for costs of third party external review and tax deductions on costs of issuance of SRI *sukuk* (Azhgaliyeva et al. 2020).

12.3.3 Green Bonds Issued to Fund Green Building Projects in ASEAN

In ASEAN, the number of green bonds issued to fund green building projects is projected to increase (Climate Bonds Initiative 2018a). Green buildings are recognized as a legitimate project that may be financed through green bonds under the International Capital Market Association Green Bond Principles (ICMA GBP) and the ASEAN Green Bond Standards (GBS). The ICMA GBP, a set of voluntary guidelines that seek to codify recommendations for transparency in the issuance of green bonds, states that green bonds may be issued to fund green building initiatives, energy efficiency improvements, and research and development in renewable energy, as well as the installation of renewable energy technology (ICMA 2018). Under the ASEAN GBS, a code of elective principles developed for the ASEAN context based on the ICMA GBP, green buildings are explicitly designated as a possible project that may be funded using green bonds (ACMF 2018).

In the ICMA Green, Social and Sustainability bonds open-access database, of the bonds issued in ASEAN countries in 2016 or later, approximately 36% were issued specifically for green building projects. The ICMA Green, Social and Sustainability bonds database is a compendium of resources on green bonds issued in 2016 or later. A list of green bonds and the projects they were issued to fund, as

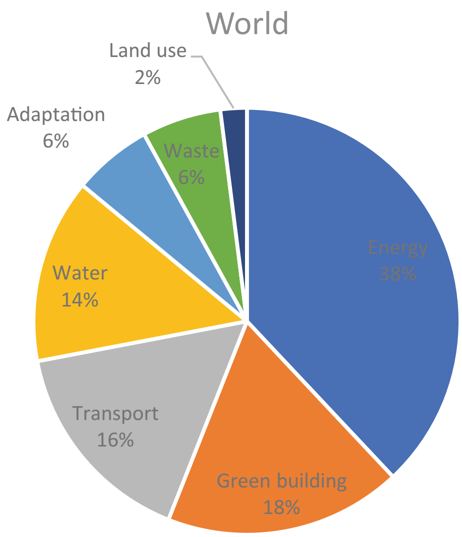

Fig. 12.4 Global use of green bond proceeds. *Source* Authors' own based on data from Filkova et al. (2018)

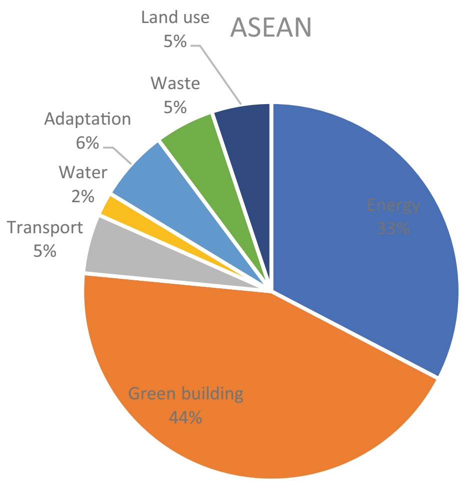

Fig. 12.5 Use of green bond proceeds in ASEAN. *ASEAN* Association of Southeast Asian Nations. Source Authors' own based on data from Filkova et al. (2018)

recorded in the database and with additional elaboration, is available in Table 12.1 in the Appendix. Another source puts the percentage of green bond proceeds going towards financing green building projects at 44% (Filkova et al. 2018). Either number obtained from the two sources is substantially above the global total, in which 18% of green bond proceeds are put towards funding green building projects. Figures 12.4 and 12.5 compare the use of green bond proceeds in ASEAN with that of the rest of the world.

12.3.4 Green Bonds as an Effective Instrument to Finance Green Buildings in Singapore and Malaysia

Since Malaysia and Singapore are the only ASEAN member states with existing green building targets, we focus our analysis in the following sections on these two countries. What factors may explain the relatively higher rate at which green bonds have been issued for green building projects in ASEAN, as compared to the rest of the world? We interpret this phenomenon through a demand-focused lens. One of the factors driving demand is that building design has a more sizeable impact on the energy efficiency of buildings in ASEAN member states than in many countries in the rest of the world, since Southeast Asia is in the equatorial belt, whereas many countries in the rest of the world are located in temperate zones. Differences in climate affect the effectiveness of building design choices, such as building finishes (Shi and Zhang 2011). A second reason is that there is a more urgent need for ASEAN countries, which experience warmer temperatures, to adapt to the pressures of climate change through emphasizing sustainability in the built environment. Global warming reduces the warming load of buildings located in colder regions, but increases the cooling load in buildings in warmer areas (Wan et al. 2011).

Green bonds appear to be a promising financing mechanism for green building projects in ASEAN, considering that a large proportion of green bonds are currently being issued to fund such projects. In this subsection, we will focus our discussion on how green bonds may help overcome existent barriers to investment in green buildings as discussed in Sect. 12.2.2, with particular reference to three green building projects for which green bonds have been issued in Malaysia and Singapore: gateway@klia2 and Merdeka PNB118 Tower in Malaysia, and Marina Bay Financial Centre Tower 3 (MBFC T3) in Singapore. We first highlight green building rating schemes in the Malaysia and Singapore contexts to foreground later analysis of these case studies.

Malaysia had set a target of 550 green-certified buildings by 2020, and aims to achieve 1,750 green-certified buildings by 2030 (Malaysian Investment Development Authority 2019). In Singapore, 3,200 buildings had achieved Green Mark certification by January 2018 (Ministry of National Development n.d.), and the current target is for at least 80% of buildings in Singapore to achieve Green Mark certification by 2030 (Building and Construction Authority 2014).

Malaysia established its Green Building Index (GBI) in 2009 and Green Real Estate (GreenRE) in 2013. The GBI is a rating tool to recognize sustainable developments in the built environment. Developments are rated “Certified”, “Silver”, “Gold”, or “Platinum” according to the number of points they are awarded in the rating system (Tan 2009). The Malaysian government has implemented incentives, such as tax exemptions, for GBI-certified buildings. These include investment tax breaks for costs incurred in the construction of GBI-certified buildings. There is evidence that GBI has accelerated the movement towards environmental sustainability in the built environment in Malaysia (Aliagha et al. 2013).

On the other hand, GreenRE was set up bythe Real Estate and Housing Developers' Association of Malaysia to drive sustainability of the real estate industry. GreenRE is fully supported and recognized by the Malaysian government and local authorities, including the Ministry of Energy, Science, Technology, Environment and Climate Change, the Malaysia Green Technology Corporation and the Malaysian Investment Development Authority. Certified projects qualify for income tax allowances and incentives under the Green Tax Incentive Scheme of the Malaysian Investment Development Authority and Ministry of Finance. Currently, GreenRE has a portfolio of projects covering more than 100 million square feet across Malaysia.

Singapore's Building and Construction Authority (BCA) established the Green Mark scheme in 2005 (Building and Construction Authority n.d.). This scheme certifies buildings in the Singapore built environment according to a codified set of criteria based on international best practices in green buildings, and further provides incentives for energy efficiency improvements made in buildings. There is evidence that suggests that the Green Mark rating scheme has made advances both in terms of improving the monitoring system for the energy efficiency performance of buildings, as well as increasing awareness of the importance of green practices in the building industry. A questionnaire distributed online found that the Green Mark scheme has improved awareness of environmental issues pertaining to the built environment among professionals in the construction industry (Ng and Runeson 2008).

We now examine the difference between green bonds and traditional sources of funding, such as loans and equity investments. First of all, the advantages of bond financing should be investigated from the perspective of financing costs. Since bonds offer the opportunity to disperse ownership of the debt across a group of investors, financiers find it easier to invest through bonds as opposed to investing through loans or equity ownership. Dispersed ownership translates to distributed risks, thus contributing to a lower risk premium and therefore lowering financing costs. Furthermore, the presence of a secondary market for bonds promotes liquidity, thereby offering financiers a short-term exit strategy and a shorter payback period. Due to the capital-intensive nature of green buildings, the initial years of the project lifecycle is likely to experience negative cash flows. Bond financing allows for delayed principal repayments, which enable projects to generate returns and cover the capital costs across the payback period (Yang et al. 2020).

For instance, on 8 November 2017, asset management firm Permodalan Nasional Berhad (PNB) issued a green *sukuk* to fund the 118-storey Merdeka PNB118 Tower, a green mixed-use building that will tap on energy-efficient technology to become certified as a LEED Platinum building (Suruhanjaya Sekuriti Malaysia and World Bank Group 2019). Green features include chilled water energy storage, solar panels, daylight sensors, tenant submetering, and energy efficient lighting (PNB 2017). At the time of issuance, this was the third largest green *sukuk* issued in Malaysia (Wahab and Mohamed-Naim 2019). The cost of this project is projected to be fully recovered only after a decade (Kana 2019). The longer term to maturity makes green bonds more suitable as a source of finance (ADB 2018), and the risk involved in this project makes green *sukuk* particularly appropriate for risk-sharing between PNB and investors. While green building financing may be considered too risky by bank lenders, risk-sharing between project developers and investors coheres with the tenets of Islamic financing, and green *sukuk* may fill a funding gap in this market (ADB 2018). Second, lenders are reluctant to lend to green building projects due to the small ticket size, and often untransparent service contracts, and a lack of expertise on energy efficiency. In this sense, bonds are better able to draw on various sources of long-term institutional and household savings, and the bond market requires higher transparency in the provision of financial and other relevant information, therefore increasing the necessity for disclosure and the access to information for all market participants (Peterson 2003).

Green bonds are more suited to green project financing than loans, as bank lenders may lack technical knowledge on energy efficiency financing (Woodroof 2009), and not prioritize environmental sustainability as a criterion in offering loans. Comparatively, investors in the green bond market are specifically interested in the greenness of the projects that they are supporting, and indicate that they favor the targeted nature of project financing, as they are able to perform their due diligence and learn more about how the projects they are considering funding contribute to sustainability (Wood and Grace 2011).

With regard to Singapore's case, transparency may have resulted in strong demand for a green bond issued by the Development Bank of Singapore (DBS). In July 2017, ahead of the issuance of a green bond for the financing of projects including Marina Bay Financial Centre (MBFC) T3 (Yoon 2017), DBS released its Green Bond Framework, a five-page document outlining criteria for the selection of green projects that will be funded by green bond proceeds (DBS Sustainability Council 2017). This document commits DBS to annual project audits and impact reporting (DBS Sustainability Council 2017), which increases transparency for investors.

Furthermore, the fact that construction on MBFC T3 had been completed earlier in 2012 and the building had been awarded the Green Mark Gold Plus for sustainability measures built into the design of the structure increases the ability of investors to assess the impact of the building (MBFC n.d.). Indeed, MBFC T3 uses special glass, landscaping, sky terraces, and gardens to reduce the amount of heat absorbed by the surface, therefore reducing the cooling load. The building also monitors outdoor temperatures to adjust indoor air conditioning. Lighting, taps, toilets, and escalators are controlled by sensors. There is a system in place to collect condensed water droplets for the cleaning of the building facilities. The energy and water use of the building is also monitored and reported frequently (Chua 2015).

In Malaysia, Segi Astana Sdn Bhd issued their first ASEAN green bond, for RM415 million ($03.7 million) in January 2018. The proceeds are designated for the refinancing of the medium-term notes guaranteed by Danajamin Nasional Berhad to fund gateway@klia2 (Chandra and Ng 2017). Segi Astana Sdn Bhd has committed itself to reporting on the energy consumption, carbon emissions, and water use of the building annually so energy efficiency improvements may be monitored (Climate Bonds Initiative 2018c). In 2014, gateway@klia2 was provisionally given a GBI gold rating (The Star 2014). The green features of gateway@klia2 include rainwater harvesting, stream waste disposal, as well as daylight sensors in the parking lot and carbon dioxide sensors in the interior of the retail building (gateway@klia2 n.d.).

In both of the above two examples, green bonds are a viable source of finance, because clear documentation of the sustainability features of the building makes investment attractive to market participants who place emphasis on environmental impact as an outcome of their investment. The codification and promulgation of local rating schemes for the greenness of buildings, Green Mark and GBI, has also certainly contributed to acknowledging the environmental impact of energy efficiency features in these two buildings. Local certification schemes are useful as they benchmark the environmental impact of green building projects for which green bonds are issued against other buildings in the country, therefore providing investors with an objective and standardized basis for comparison. Furthermore, while investors may not be able to assess what absolute quantity of energy performance improvement should be considered large, green building certification provides a normative interpretation of the environmental impact of various buildings. Such features may not command a premium in other financing markets but are appreciated in the green bond market.

12.3.5 Challenges in the Widespread Adoption of Green Bonds to Finance Green Building Projects

Green bonds address more financing barriers to energy efficiency compared to other financing instruments. Remaining challenges to unlock the full potential of the bond market are mainly two-fold.

First, as project sponsors that wish to raise funds may not possess experience in creating a green bond framework, they may be averse to utilizing this financing mechanism, particularly in jurisdictions where a policy framework has not yet been established. Indeed, the process of creating such a framework has proved difficult and onerous, as it requires both a relatively advanced bond market and green building certification schemes (Lai 2019). Therefore, the costs of acquiring information on the process of issuing a green bond and the requirements to be met in such a process may deter potential market participants from entry, and these costs are compounded by inconsistency across and ambiguity in green bond standards (Ehlers and Packer 2017).

On the other hand, although green bonds gain increasing penetration into the ASEAN market, it is found that the current investors are more motivated by a green reputation or corporate social responsibility rather than higher yield. Available literature finds that on average, there is no robust and significant yield premium or discount on green bonds, when comparing liquidity-adjusted yield premiums of green bonds to conventional bonds. However, green bonds certified by an external reviewer enjoy a discount of about 6 basis points. Furthermore, green bonds that obtain a Climate Bonds Initiative certificate show a discount of around 15 basis points. The findings suggest that a universally accepted greenness measure can benefit the development of the green bond market (Hyun et al. 2020). Banga (2019) identifies perceived high transactional costs as one of the factors that deter firms from issuing green bonds. These barriers to adoption may all be overcome with a robust institutional framework and an increasing number of green bonds issued in ASEAN nations to build local capacity and expertise.

12.4 Conclusion and Policy Recommendations

As energy demand increases in ASEAN, member states must look towards policy solutions that increase energy efficiency. Buildings are a major source of energy consumption and therefore increasing the energy efficiency of buildings should be an area of focus for governments in the region. Presently, under-investment in green buildings occurs as market participants are underinformed about energy efficiency equipment and the actual costs of green building construction, and experience structural disincentives from investment. Green bonds enable building developers to access external capital, especially ethical investment funds, without the imposition of restrictive covenants. They further allow developers to promote themselves as sustainable. Therefore, they present an attractive alternative to traditional sources of financing.

Green bonds have already been successfully issued to raise funds for several green building projects in Malaysia and Singapore, as laid out above, such that the outlook on more widespread adoption of green bonds as a financing mechanism for green buildings appears sanguine. However, obstacles to the prevalent issuance of green bonds remain. Building developers may be averse to capitalizing on the global growth in the green bond market due to limited information on and experience in the process of issuing green bonds. This section concludes with policy recommendations for future use of green bonds for funding green building projects.

12.4.1 Enabling the Demand for Green Bonds Through Information Provision

There remains an information gap in the ASEAN market for green bonds since, as impact investing and the green bond market are in their nascent stages, market participants lack the technical expertise and institutional memory to appropriately assess the potential payoffs (Castillejos-Petalcorin et al. 2018). Castillejos-Petalcorin et al. (2018) further find empirical evidence that information on the environmental sustainability of the projects the green bond is meant to fund is associated with a payoff in market premium. Therefore, green bond issuers should increase the amount of information provided to potential investors, such that participation becomes more transparent and is associated with less risk.

As explained above, green building projects may enjoy an advantage in this regard, due to the available certification schemes through which they may gain credibility. However, since under most rating systems, projects are only certified after completion, a pre-assessment of the building design and conditional conferment of a rating may be in order so as to fully capitalize on existing certification schemes. Additionally, a general increase in familiarity with green building certification schemes may make information on green building projects more accessible to investors, since certification validates the environmental impact of the project.

There are several ways through which ASEAN governments can facilitate local issuance of green bonds. One of the ways is to increase the number of consultations and information sharing sessions to disseminate information on green bond standards and what constitutes greenness in accordance with such standards, in order to demystify the project requirements to issue a green bond. Second, within the regional bloc, ASEAN corporations may establish a network to pool expertise and information on key green bond issuance tasks that may be difficult for first-time issuers such as the drafting of a green bond framework and the marketing of green bonds. A third solution that governments may implement is to subsidize the transaction costs incurred in the issuance of a green bond, as suggested in Banga (2019). Such a scheme already exists in Singapore, where the Monetary Authority of Singapore (MAS) began the Sustainable Bond Grant Scheme that subsidizes eligible costs associated with the issuance of a green bond (Monetary Authority of Singapore n.d.).

12.4.2 Endorsement of Green Buildings Through Building Codes

In addition to increasing access to and the amount of information on projects, we further note that it is no coincidence that Malaysia and Singapore, the two countries in ASEAN with the largest focus on green building initiatives and which have established supplementary incentive schemes, have the highest number of green bonds issued for green building projects. Governments in all ASEAN member states should actively encourage higher environmental sustainability in the built environment and cooperate with local building developers to increase environmental awareness and knowledge of developments in green buildings. Where possible, incentive schemes may also be initiated to further defray the costs associated with energy efficiency improvements in buildings.

The lack of investment in green buildings and energy efficiency may be attributed to these investments being “less visible” than renewable energy investments, primarily due to the lack of a credible, uniform and standardized building energy performance certification and rating system adopted in many countries. Due to the asymmetry in visibility, banks are disproportionately more interested in funding renewable energy as compared to energy efficiency investments due to the former's clear revenue streams and benefits. In Malaysia, it was noticed that a noticeable lack of transparency in service contracts between project developers and financial institutions, as well as ambiguous project approvals, led to underinvestment in energy efficient technologies (ACE 2019). In the absence of visibility, energy efficiency investments become hard to value (UN ESCAP 2012).

12.4.3 Promoting Local Currency Bond Financing Through Domestic Institutional Investors

There are few responsible, sustainable, or green investment mandates among domestic institutional investors across ASEAN. The size of the domestic finance sectors, particularly nonbank institutional investors, is relatively small relative to the needed infrastructure investments (ADB 2018). Therefore, increasing the demand of domestic institutional investors for green bonds is essential to catalyzing the market-driven development of domestic green bond issuance. For this, there is a need to link the importance of green bond markets to the countries nationally determined contributions as part of the Paris Agreement or overall Sustainable Development Goals. This would lead to increased awareness of various institutional investors to access local markets.

Meanwhile, it is also important to develop a sound framework for public–private partnerships (PPPs) in the domestic market. PPPs are known for their efficiency in delivering public infrastructure and services. Technical skills and experience may be lacking within many public entities responsible for infrastructure development, and thus collaboration with the private sector to pool expertise is in order. A shift away from a low-bid approach in infrastructure procurement towards evaluating life cycle costs is recommended to improve the quality of infrastructure projects. The PPP model works well to embed life-cycle costs of green buildings in the procurement process. A survey of the literature finds that PPP is more costly than public procurement (Petersen 2019). Makovšek (2013) finds evidence that risk cannot fully account for this increase in cost. Theoretically, firms with relevant expertise should be better able to assess and optimize life-cycle costs in further maintenance and operation of green buildings (Makovšek 2013).

In conclusion, the potential for green bonds as a funding source for green buildings in ASEAN is not to be underestimated. While the green bond market in ASEAN is currently small, there is large potential for growth. Green bonds can complement traditional modes of financing for green buildings, such as bank loans. This chapter highlights the need for the market to provide information on greenness. Extant certification schemes for green buildings lend to the credibility of green building projects and information availability with the green bond markets, increasing the attractiveness of green bonds issued for green building projects. Individual bond issuers should work towards audits of their projects, and government agencies should consider conditionally certifying projects based on the blueprints for construction. Furthermore, government endorsement through establishing green building targets and promoting awareness of and attention to the energy efficiency of buildings will be a further step toward tapping green bond markets as a source for financing for green building projects in countries in ASEAN. Finally, governments should encourage local currency bond financing through institutional investors. Overall, green bonds are a suitable mechanism for financing green bond projects, and governments and building developers should give closer scrutiny to this source of funding.

Appendix

See Table 12.1

Table 12.1 Green bonds issued in ASEAN since 2016

Country	Bond issuer	Year	Type	Purpose
Indonesia	PT Sarana Multi Infrastruktur	2018	All	To fund projects in renewable energy, energy efficiency, sustainable pollution management and prevention, sustainable natural resources and land use management, clean transportation, and sustainable water and sewage management (PT SMI 2018)
Indonesia	Republic of Indonesia	2018	All	To fund projects that mitigate the impact of climate change, reduce the environmental footprint, and conserve biodiversity (BioDiversity Finance Initiative 2018)
Indonesia	Star Energy Geothermal (Wayang Windu)	2018	Renewable energy	To fund the Wayang Windu geothermal power plant (Climate Bonds Initiative 2018d)
Malaysia	Segi Astana	2018	Energy efficiency – Green buildings	To fund gateway@klia2, a green building (Climate Bonds Initiative 2018c)
Malaysia	Mudajaya Group Berhad (Sinar Kamiri)	2018	Renewable energy	To fund a solar PV plant in Perak, Malaysia (Climate Bonds Initiative 2018b)

(continued)

Table 12.1 (continued)

Country	Bond issuer	Year	Type	Purpose
Malaysia	Tadau Energy	2017	Renewable energy	To fund a solar project in Sabah, Malaysia (CICERO 2017)
Philippines	AC Energy Finance International	2019	Renewable energy	To fund renewable energy and thermal energy generation facilities (AC Energy n.d.)
Philippines	Arthaland Corporation	2020	Energy efficiency – Green buildings	To fund the development of green buildings (Arthaland Corporation n.d.)
Philippines	Bank of the Philippine Islands	2019	All	To fund projects that fall under the Bank of the Philippine Islands Green Finance Framework (Patrini 2019)
Philippines	Rizal Commercial Banking Corporation	2017	All	To fund loans disbursed for green projects (Dumlao-Abadilla 2019)
Singapore	City Developments Limited	2017	Energy efficiency – Green buildings	To repay a S$100 million (approximately US$70.8 million) loan it took to retrofit Republic Plaza to make sustainability improvements (Shah 2017)
Singapore	Oxley Holdings Limited	2020	All	To fund projects in (i) green buildings, (ii) renewable energy, (iii) energy efficiency, (iv) clean transportation, (v) pollution prevention and control, (vi) sustainable water and wastewater management, and (vi) climate change adaptation
Singapore	Sindicatum Renewable Energy Company	2018	Renewable energy	To fund renewable energy projects, waste-to-energy projects, and bagasse-cogeneration projects (Sustainalytics 2017)
Singapore	Soilbuild Group	2019	Energy efficiency – green Buildings	Soilbuild Group, a Singaporean real estate developer, will be using the bond proceeds to build a Green Mark Platinum business space, Solaris @ Tai Seng (Climate Bonds Initiative 2020)

Source Climate Bonds Initiative

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Chapter 13
Energy Efficiency Financing in Viet Nam: Current Status and Solutions Toward Market-Based Mechanism Adoption

Le Ngoc Dang and Farhad Taghizadeh-Hesary

Abstract In Viet Nam, energy efficiency and conservation are playing an increasingly important role in serving sustainable economic development goals through tackling the threat of energy supply insecurity while enhancing resource efficiency and effectiveness. In the national energy efficiency program, the government set the target of saving 7.0% of the energy consumption in the period of 2019–2030 (Government of Viet Nam (2020)). Although there are a number of fiscal measures with major government-led financing facilities dedicated for energy efficiency (EE) technologies with preferential term loans coupled with technical assistance, EE investment in Viet Nam is still at a nascent stage and leaves room for development in the coming time. The impediments preventing EE investment come from lacking the motivation to adopt EE technologies as a result of low energy (electricity) costs; the reluctance of the domestic financial market in financing EE projects when professional expertise is unqualified and inexperienced to confidently implement credit appraisals and lending decisions to the EE that is perceived as a niche, and a new segment with the high level of credit risk. Besides, the underdevelopment of energy saving companies' operation in offering EE solutions and financing options is also an issue resulting in an immature EE investment environment in the country. To achieve the national target of EE and scaling-up EE investment with the outlook of market-based solutions for EE in Viet Nam in the future, major recommendations include focusing on dedicated EE facilities to energy-intensive industry, promulgating necessary regulations and policies to facilitate energy saving companies, and amending and revising the electricity pricing policy to increase users' motivation to EE technologies. Besides, building a comprehensive energy efficiency database system for should be more focused.

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JEL Classification F21 · H23 · Q42 · Q54 · Q58

13.1 Introduction

The Government of Viet Nam has made energy conservation one of its top priorities and considers energy efficiency as one of the lowest cost options for addressing the increasing energy demand, and serving economic development with committed environmental protection goals. In early 2020, by promulgating Resolution No. 55-NQ/TW on the orientation of Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045, the government re-affirms the importance of energy efficiency technology adoption to the national energy security and targets the ratio of energy savings to total final energy consumption of the country compared to the average development scenario at 7% in 2030 and around 14% by 2045 (Government of Viet Nam 2020).

To achieve that goal, the industrial sector is a central focus to ensure the program's success with specific targets such as 3%–10% for steel industry depending on product type and production technology; a minimum of 7% for the chemical industry; from 18–22% for the plastic manufacturing industry; a minimum of 7.5% for the cement industry, and a minimum of 5% for the textile and garment industry (Government of Viet Nam 2019).

Given the recognition by the government on the importance of energy efficiency, a number of a complementary set of policies have been issued and implemented. However, lessons and experiences learned in scaling-up energy efficiency investment in Viet Nam indicated that the adoption of energy efficiency technologies faces many obstacles and risks, and EE investment is lagging the levels reached in neighboring countries such as the Philippines and Thailand (Copenhagen Centre on Energy Efficiency 2015). Retallack et al. (2018) state that the lack of familiarity and trust from end users and investors in business models that monetize energy savings, such as energy service companies (ESCOs) offer, can represent a crucial barrier. This makes it difficult for companies based on these business models to raise capital. To solve this problem, schemes can implement support for de-risking investments in ESCOs to encourage growth in their business model.

Difficulty in accessing finance is also considered one of the significant barriers to the energy efficiency market in Viet Nam. The lack of financing sources impedes the uptake and deployment of more energy efficient practices of industrial production, despite projects being recognized where considerable savings in both energy and cash are feasible. Currently, seeking energy efficiency investment can be through preferential financial instruments including investment grants, partial loan guarantees, and risk-sharing facilities from the state budget with support from international donor programs. At the same time, financial vehicles from commercial debt financing for EE are lacking where the banking sector is relatively underdeveloped, commercial banks are illiquid and unwilling to accept some risks, and market baseline activity is insufficient—projects have been implemented to underwrite partial-risk and credit guarantees to ESCOs, end users, small and medium-sized enterprises (SMEs), industries, and municipalities.

Given the current circumstances in EE investing in Viet Nam, ways forward should focus on dedicated EE facilities to the core energy-consuming industries with lessening the EE lending conditions for those segments; promulgating necessary regulations and policies to facilitate ESCOs operation should be a priority in the near future. Moreover, amendment and revision of electricity pricing is necessary to increase end users' acceptance of EE technologies as well as building a comprehensive database system for EE.

13.2 Current Status of Energy Efficiency in Viet Nam

13.2.1 Energy Conservation Potential in Different Sectors of the Economy

Viet Nam has an unusually high energy consumption per unit of gross domestic (GDP). In 2015, the primary energy intensity with respect to GDP was 20 gigajoules (GJ) per $16 (World Bank 2016), while the world average amounted to 8 GJ/$. Figure 13.1 shows the amount of primary energy megajoules per GDP purchasing power parity. At present, Viet Nam's energy intensity is 5.94; higher than the

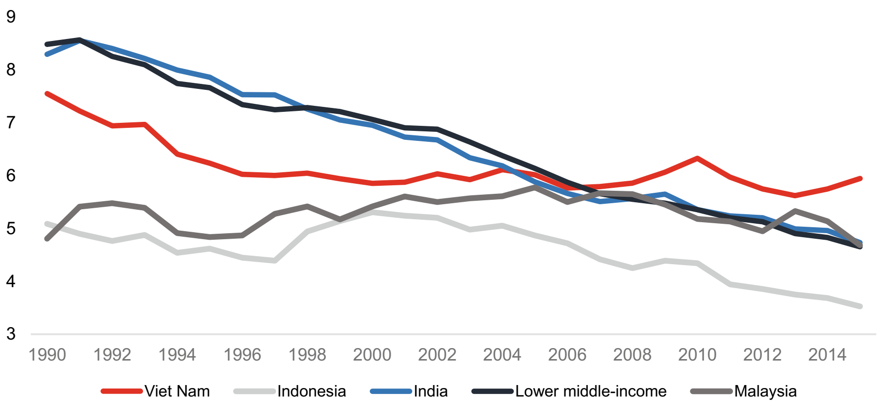

Fig. 13.1 Energy intensity level of primary energy (MJ/$2011 PPP GDP). *GDP* gross domestic product, *MJ* megajoule, *PPP* purchasing power parity. *Source* World Bank (2016)

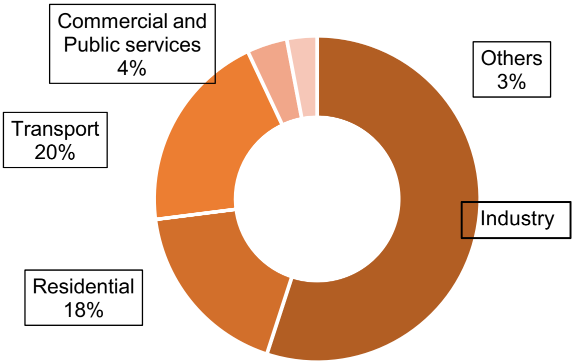

Fig. 13.2 Energy consumption by sector (2017). *Source* IEA (2019)

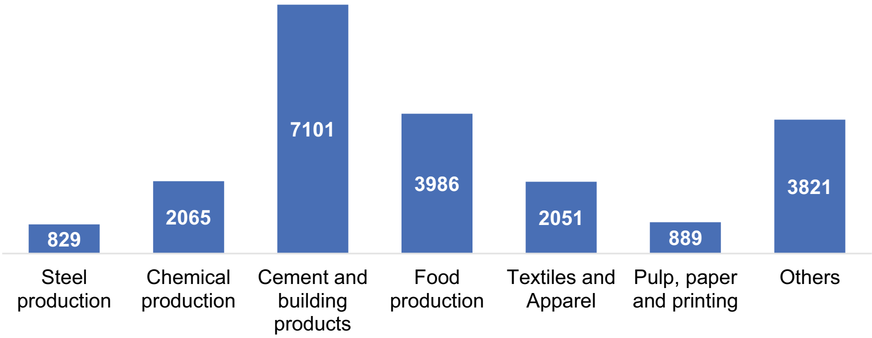

Fig. 13.3 Energy consumption in the key industry (Ktoe). *Ktoe* kilotons of oil equivalent. *Source* Government of Viet Nam (2015)

average of lower middle-income countries (4.65) and other economies in the region (Malaysia [4.68], Indonesia [3.53], and India [4.73]). This reflects that Viet Nam is using much more energy for a unit of economic output.

Energy demand is increasingly remarkably to serve industrialization in Viet Nam with an average of 10% annually. Among economic sectors, industry is the engine and driving force for economic development, but at the same time, this is the most energy-intensive one, accounting for almost half of energy consumption in the country (Fig. 13.2).

Energy intensity is expected to continue in the same pattern in the industrial sector in the coming years as Viet Nam is still in the industrialization process. The energy intensity of Viet Nam's industry subsector and fuel expenditure per product unit is higher by roughly 1.5 times compared to neighboring countries (World Bank 2019). Cement and building products, food production, and "others" are the most intensive in the industrial category (Fig. 13.3), followed by textiles and apparel; chemical production; pulp, paper, and printing; and steel production.

The industrial sector has the highest potential for the adoption of energy efficiency techniques. As planned in the National Energy Efficiency Program (Government of Viet Nam 2019) the reduced energy rate against energy

Table 13.1 Energy conservation potential in key industries

Industry	Product	Specific consumption		Saving potential (%)
		Total	Unit	
Beverage	Beer	355	MJ/100 L	9–12
	Non-alcohol beverage	78	MJ/100 L	4–9
Paper	Paper powder	3,990	MJ/ton	6.8
	Packaging	7,166	MJ/ton	3.8
	Printing paper	9,804	MJ/ton	4.4
	Toilet paper	11,443	MJ/ton	3.8
Chemical production	Rubber SVR 10 CV, 20CV	37	kgoe/ton	9.4–32.7
	Rubber SVR 10, 20	55	kgoe/ton	9.8–32.7
	Fertilizer	25	kgoe/ton	1.4–5.4
	Water-based paint	6.0	kgoe/ton	20–30
Heavy industrial products	Finished steel products	179	kgoe/ton	13
	Cement	97	kgoe/ton	14
	Textile	177	kgoe/ton	14

Kgoe kilograms of oil equivalent, *MJ* megajoule. *Source* Government of Viet Nam (2019)

consumption, including noncommercial energy with the potential of energy savings are 14% for cement and textiles, 13% for steel products, and wider ranges of 9.4%–30% for chemical production and 4%–12% for beverages (Table 13.1).

In addition to the industrial sector, the rest of the economy including agriculture, services, and transport is also suffering from low energy efficiency issues and leaves room for improvement (Fig. 13.4).

13.3 Financing for Energy Efficiency in Viet Nam

13.3.1 Energy Efficiency Investment Need

Given Viet Nam's energy intensity, which is among the highest in the world but at the same time it indicates high savings potential particularly in the industrial sector, the government has promulgated a number of policies regulating energy efficiency in the country. The fundamental goal is set under the Vietnam National Energy

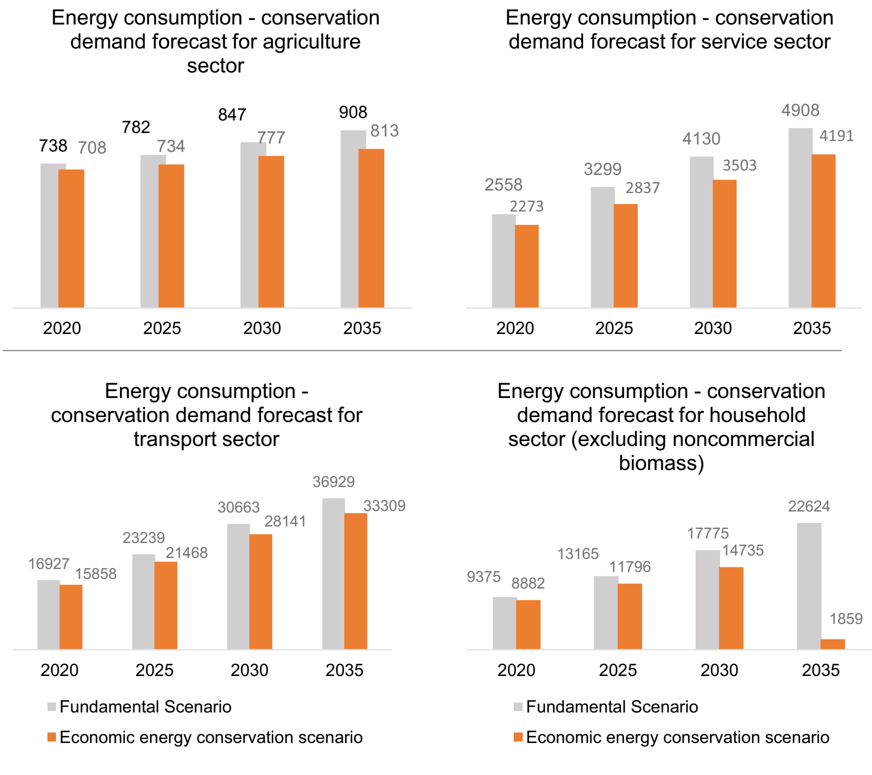

Fig. 13.4 Energy consumption – conservation demand forecast for key sectors (Ktoe) *Ktoe* kilotons of oil equivalent. *Source* Government of Viet Nam (2015)

Efficiency Program (Government of Viet Nam 2019) setting its target at 8–10% conservation from total nationwide energy consumption against the energy need forecast in the National Power Development Plan VII revised consideration to 2030, which is equivalent to 11 million to 17 million tons of oil equivalent (toe) (Government of Viet Nam 2016).

To achieve that goal, a huge investment is needed from stakeholders including the government, energy-end users, and supporting international donors. As for the industrial sector, an estimation of $1.4 trillion dollars is required to invest in energy efficiency technology (Government of Viet Nam 2015). At the same time, the estimated finance sources mobilized from the government budget and supporting donor funds are above VND10,000 billion (above $400 million), that investment demand is expected to be allocated from the state, private investment, and bilateral and multilateral official development assistance (ODA). Funding from the state budget is estimated at VND4,400 billion comprising: nonbusiness economic expenditure from the central budget reserved for energy saving is about VND600 billion; nonrefundable aid expected at about VND1,600 billion from bilateral and multilateral support programs; and concessional loans (mostly from the official development assistance loans) estimated at VND2,200 billion. Capital for investment in the field of energy saving from domestic credit institutions is estimated at around VND5,000 billion. Except for the funding resources from public and donor funds, the large proportion of investment for EE will be from the energy-utilizing enterprises and energy service companies (ESCOs) to make use of their funding to secure energy efficiency and conservation.

The government's goal is to achieve energy efficiency in the upcoming period of 2020 to 2030; finding financial sources for unlocking EE potential is a challenge. In the long term, the investment needs in several key energy-intensive industries, such as cement, steel, pulp and paper, seafood processing, and chemical production are huge according to a recent study conducted by the Ministry of Industry and Trade (Government of Viet Nam 2015). The investment needs for steel and chemical production share the largest proportion with $671.96 million and $400.78 million, respectively. From the total investment need, energy-saving potential was estimated to be 8.29 million toe per year, and greenhouse gas emissions reduction to be 43.47 million tons of carbon dioxide equivalent (tCO_2eq) per year.

13.3.2 Financial Instruments to Unlock Energy Efficiency Potential in Viet Nam

Energy efficiency investment in Viet Nam is at the nascent stage and is still going through the preliminary phases of awareness building about the need for energy efficiency, regulatory reforms, as well as demonstrating successful models of energy efficiency projects. Those government-led investment mechanisms have been predominantly funded through dedicated credit lines such as energy efficiency funds that have been established by the government and international donors.

- **Energy Efficiency Tax Relief**

Tax relief is one of the fiscal instruments to attract energy efficiency investment. Since 2016 a preferential corporate income tax rate of 17% applied during a period of 10 years for business activities performing new investment projects including manufacturing energy-saving products and investment in energy-saving industry (Government of Viet Nam 2014).

- **Public Sector Loans and Guarantee Programs**

International experience demonstrates that dedicated credit lines are effective at increasing the professional capacity, interest, and confidence of financial institutions (commercial banks) in EE financing business. This approach can achieve a double leveraging effect by mobilizing substantial debt contributions from financial institutions and equity financing from end beneficiaries and then revolving the loans that are repaid to the funds. Supported financial institutions (commercial banks) will continue to provide EE financing after the completion of credit line programs. This is considered as an appropriate model for EE financing in Viet Nam given the immature market in this field.

As of now, there are several major funding schemes that focus on EE financing within this funding type: the Vietnam Environmental Protection Fund (VEPF) and the Vietnam Energy Efficiency for Industrial Enterprises Project (VEEIE) from the World Bank as well as other international donors.

- **EE Financing through Viet Nam Environment Protection Fund (VEPF)**

The VEPF is operated by the Ministry of Natural Resources and Environment that finances environmental protection activities including energy conservation projects. The VEPF is responsible for controlling funds allocated from the central government budget as well as foreign donors and the private sector for key environmental protection activities. The VEPF provides financial support to eligible organizations and individuals through a variety of financial instruments including concessional loans, debt guarantees, and cofinancing. The state budget is the primary source of VEPF capital with an annual budget allocated of VND500 billion ($24 million).

Industrial enterprises can approach the VEPF when implementing EE investment with loans embedded with preferential conditions including:

- Interest rate: The common principle for determining the annual loan interest rate is equal to 50% of the basic interest rate set by the government. In 2019, the interest rate for projects in its priority list or with a bank guarantee is 2.6% and for other projects 3.6%, and fixed during the term of the loan (up to 10 years) and with a 2-year grace period. The interest rate of overdue debt will be 150% of this rate.
- Loan amount: The maximum loan amount for a project is up to VND50 billion (5% of VEPF's charter capital), but not over 70% of total investment. The loan amount per investor must not exceed 10% of the VEPF's charter capital.
- The maximum loan amount is only equal to 70% of collateral value. With loan guarantees from commercial banks or savings banks, investors can borrow 100% of the guaranteed amount.
- Post-investment interest rate support: 4% per year (since 2018)

The preferential loan interest rate and post-investment interest rate support are announced annually by the VEPF's management council. In case enterprises apply for support and the VEPF has not yet issued preferential interest rates for that year, the preferential interest rate or post-investment interest rate support of previous year is applied.

- **EE Financing Through Soft Loans Provided by International Donor Programs**

In Viet Nam, EE financing programs under these channels come from bilateral and multilateral ODA. Through those programs, the partner financial institutions (often commercial banks) will receive the dedicated loans for EE and then will on-lend to customers deploying EE technologies.

- Vietnam Energy Efficiency for Industrial Enterprises Project (VEEIE)

The VEEIE is a project implemented by the World Bank and managed by the Ministry of Industry and Trade with a total value of $158 million from 2017 to 2022 (World Bank 2017). The project has the participation of commercial banks including the Joint Stock Commercial Bank for Investment and Development of Vietnam and the Joint Stock Commercial Bank for Foreign Trade of Vietnam. Those partner financial institutions (PFIs) were selected basing on financial and nonfinancial criteria that demonstrate EE lending strategy and/or commitment, experience, and ability to design and finance a solid EE project pipeline. The World Bank funds are allocated among selected PFIs based on the proposed pipeline and remaining funds will be channeled on a first-come, first-served basis. The lending rate is decided on market conditions to ensure an adequate covering for the financing and operating expenses and offer a reasonable profit margin for the PFIs.

The project aims to help remove the principal barriers to investments in industrial EE projects. Technical assistance and capacity building activities will enhance the knowledge, institutional, and capacity shortage of the banking and industrial sectors, mitigate perceived risk concerns from private firms in EE investment, and strengthen government supervision of industrial energy conservation. Those efforts will be accompanied by the International Bank for Reconstruction and Development (IBRD) lending program for EE in Viet Nam, which will demonstrate viable and innovative mechanisms for financing industrial EE investments, in direct support of the government's EE targets and green growth strategy. The establishment of a risk-sharing facility, backed by the IBRD green credit fund guarantee instrument, will further address concerns of local financial institutions on the performance of EE investments and mitigate the credit risk of loans extended to industrial enterprises for EE, and thus encourage scaling-up of EE loans in the market.

The project has been supporting finance for various subprojects under energy-intensive industries such as cement, iron and steel, and pulp and paper through using potential energy-saving measures such as (i) the adoption of energy efficiency technologies (e.g., efficient industrial boilers, kilns, and heat exchange systems); (ii) recovery and utilization of waste and waste heat; (iii) installation of highly efficient mechanical and electrical equipment (e.g., motors, pumps, heating, and ventilation equipment); and (iv) industrial system optimization to reduce energy use. The use of renewable sources to decrease fuel and/or electricity consumption in industrial enterprises is also considered, including cogeneration facilities or process furnaces and stoves and solar water heaters for sanitary hot and/or warm preparation.

The green credit fund risk sharing facility mobilizes additional lending from PFIs' own resources by mitigating credit risks associated with commercial loans to industrial enterprises for energy efficiency purposes. The objective of the facility is to employ partial credit risk guarantees to channel private-sector lending and equity and contribute to developing a market for commercially financed and bankable energy efficiency investments. Taghizadeh-Hesary and Yoshino (2020) also indicated in their study that designing an appropriate green credit guarantee scheme is a practical solution to mitigate the credit of the energy efficiency projects. The partial credit guarantees can be effective in enhancing creditworthiness and easing collateral requirements of potential borrowers, incentivizing banks to lend at more attractive terms. Currently, financial institutions' lack of understanding and perceived high risk on energy efficiency investments make it more difficult for industrial enterprises to borrow for such projects than for normal business purposes. Eligible industrial enterprises would be borrowers under the facility; they would benefit from access to financing at more competitive terms and at lower collateral requirements than would be available to them on a stand-alone basis. PFIs as lenders under the component would benefit from low-cost credit risk mitigation and access to new lending opportunities in the area of industrial energy efficiency. The expected impact of the facility would be to crowd in additional investment in EE, expanding the EE market beyond what the energy end users can finance through the dedicated project.

- **Direct Subsidies**

In addition to the preferential lending program, the government provides direct subsidies to reduce the initial cost of EE investment and help unlock energy savings in the society. However, the number of EE subsidy programs in Viet Nam is limited and they are often a part of grants from international donors. An example is the Green Investment Support Program supporting small and medium-sized enterprises (SMEs) in energy efficiency adoption from the Denmark government. The program was established by the Embassy of Denmark in cooperation with the Ministry of Industry and Trade in 2015 and 2016 to encourage investment in the energy-efficient sector for SMEs with generous borrowing conditions and the direct rebate from actual energy efficiency saved from applying new EE technologies. The conditions to borrow money are (i) the maximum limit of credit guarantee currently applied for each project is fixed at VND4 billion, and (ii) the maximum limit of the energy-saving bonus currently applied to each project is fixed at VND1.2 billion and needs to be raised to VND2.4 billion. The compensation for energy saving criteria for reward payment is illustrated in Table 13.2.

Besides, given the lack of expertise in SMEs preparing borrowing documents and demonstrating effectively their business plans to meet the basic criteria requirements, the program also supports payments between VND6 million and VND25 million for each project for hiring specialists in helping project appraisal preparation.

Another example is the Global Climate Cooperation Fund (GCPF) credit program in cooperation with VietinBank. The program was established in 2018 to finance energy-saving and energy-efficient projects with a total capital of up to $25 million. The program is for customers who are established and operate in

Table 13.2 Direct rebate for energy efficiency conservation in different levels

Energy saving	Energy efficiency scale of reward payment
Energy conservation $\geq$ 50%	30% of loan value
45% $\leq$ Energy conservation < 50%	27% of loan value
35% $\leq$ Energy conservation < 40%	20% of loan value
30% $\geq$ Energy conservation < 35%	16% of loan value
25% $\leq$ Energy conservation < 30%	13% of loan value
20% $\leq$ Energy conservation < 25%	10% of loan value

Source VNEEP (2016)

accordance with the law and have a project or plan to improve energy efficiency and must be able demonstrate a minimum of 20% of energy or a minimum of 20% of CO_2 emissions reduction through EE investment.

The program can apply to projects such as:

Installing energy-efficient lighting in factories, commercial centers, hotels, and commercial and/or residential buildings.

Using energy-efficient energy in public buildings and large hotels to upgrade new equipment, including upgrading heating, cooling, and air conditioning.

Replacing outdated refrigeration equipment and installing room temperature controls.

Using solar energy or heat pumps to heat water.

Installing equipment for ventilation fans and water pumps.

Replacing and improving boilers and furnaces, upgrading production processes, and improving efficiency in power plants.

Recovering waste energy for power generation and/or production.

13.4 Barriers in Accelerating Energy Efficiency Financing in Viet Nam

EE financial mechanisms employed in Viet Nam are based on government-led models rather than market-based initiatives that require economically viable EE projects and more participation from private players in the field. In research conducted by Dang and Taghizadeh-Hesary (2019), the authors prove that private investment is essential to ensure a smooth and effective energy transition and avoid energy insecurity through energy efficiency and demand side management.

However, significant barriers remain during the process of energy-saving implementation. Even with the preferential funding terms to EE projects through international ODA support sources, the disbursement rate of those projects is low compared to the overall target and plan.

Taking the VEEIE from the World Bank for example, this is an intensive and ambitious program focusing on EE technology enhancement in industrial sectors.

Table 13.3 VEEIE outcomes from EE indicators and targets as of May 2020

Criteria	End target (until 31 July 2022)	Actual current (until 14 May 2020)
Projected lifetime energy savings -Megawatt hour (MWh)	4,639,000.00	334,150.00
Number of industrial enterprises adopting improved EE technologies	25	6
Annual GHG emissions avoided in IEs (tons of CO_2 equivalent)	5,027,000.00	201,413.00
Number of EE bankable projects developed	60	13
Disbursements (by loan)	-	23%

EE energy efficiency, *GHG* greenhouse gas, *IE* industrial enterprise. *Source* World Bank (2020)

However, by 14 May 2020 (half way through the project), the reimbursement rate is insignificant and small at only 23% (Table 13.3).

EE energy efficiency, *GHG* greenhouse gas, *IE* industrial enterprise. *Source* World Bank (2020)

Another example is the Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam project funded by the United Nations Development Programme that witnessed the same situation in the disbursement for financing and cofinancing. At the time of the mid-term report for monitoring and evaluation, the project was already more than halfway through its overall duration but its disbursement rate was too low (disbursed only $1,196,844 equivalent to 37% of the total grant). Nearly two-thirds of the total budget needed to be disbursed with less than 1.5 years remaining (January 2019 to April 2020, the official closing month). The major concerns, therefore, are how to increase the disbursement rate and implementation progress in its remaining duration (UNDP 2019).

The constraints to EE project investment support are usually not due to the financial viability and maturity of EE technologies but to market failures and barriers, which include:

- *Low or subsidized energy pricing that reduces motivation to invest in EE technology from energy-intensive industrial firms*

The cost of energy consumption particularly in the industrial customer segment has been low and subsidized, although this issue is currently being tackled through a series of energy pricing and electricity tariff reforms. The energy expense accounts for a relative share of operating costs, which has lessened consumers' motivation in energy conservation. The average tariff has gradually climbed from VND1,053 per kilowatt hour (kWh) in 2010 to VND1,622/kWh in March 2015 and 1,864 VND/kWh in March 2019 (equal to approximately $0.08/kWh). However, this is still significantly lower than the rate of neighboring countries such as Thailand ($0.12/kWh), the Philippines ($0.19), and Indonesia ($0.10) (Globalpetrolprices 2019). The ongoing sector reform is expected to achieve full cost recovery tariffs, which will help address one of the major barriers of low electricity pricing, to promote investments in energy efficiency technologies.

- *Immature financial system with risk aversion for EE financing and limited expertise in EE credit appraisal*

Despite the high financial viability and potential of EE investments in the industrial sector, most industrial enterprises with high energy intensity face difficulty in accessing finance. Most local financial institutions lack inhouse technical expertise to appraise EE investments and view EE lending as risky, leading to high collateral requirements to EE borrowers. In particular, the concept and practice of project-based financing that focuses on cash flows derived from energy savings have not yet been widely accepted and employed by financial institutions and also hinder the thriving ESCO model. The unqualified expertise, low interest, and confidence in EE financing on the part of financial institutions lead to insufficient financing sources for the capital expenditure of EE investments.

Despite the concessional loans distributed via commercial banks from bilateral and multilateral donors (the VEPF, World Bank program, and ODA funds from Denmark and the Republic of Korea), the interest rate and payback period are still barriers to corporations seeking EE technology solutions. Under the previous National Energy Efficiency program (2006–2015), the support mechanism for companies on replacing outdated production lines with ones applying high-performance and energy-efficient technologies encountered many drawbacks. The target program's support at 30% of the total investment fund for production lines and equipment utilizing high-performance technology with up to VND5 billion for each entity does not attract large enterprises to make investments in production line replacement as this aid is far lower than their total initial investment. Difficult borrowing conditions are also witnessed in the lending scheme from the VEPF when the fund requires a maximum loan amount that is only equal to 70% of collateral value. This is a barrier to the corporations having limited collateral in place particularly, the SMEs. Those types of conditions prevent the energy end users, particularly industrial enterprises, from effectively seeking viable financing options in funding for their EE enhancement technology.

- *Lack of an effective regulatory framework to deploy the ESCO model in the EE market*

Industrial enterprises are the main beneficiaries of EE investments but they have inadequate information of their energy efficiency potential and suitable measures that can be unlocked and adopted.

International experience demonstrates that the development of ESCOs and a functional energy performance contracting market is critical for scaling-up energy efficiency investment by addressing the inadequate number of professionals in EE from end users as well as offering additional financial options. ESCOs provide a wide range of solutions in energy management for industrial firms from energy financing, technical engineering expertise, and consultant or energy audits to installation, operation, maintenance as well as upgrading, monitoring, and assessing the energy-saving performance. Therefore, this type of company will be helpful in addressing various problems related to the energy inefficiency practice of firms. In Viet Nam, the lack of effective ESCO operation causes narrow investment options to firms seeking EE financing (USAID 2019).

However, the ESCO market in Viet Nam is at a nascent stage. There are currently about 70 energy service providers that could potentially be considered as ESCOs—mostly SMEs. Three fundamental barriers are hindering the development of ESCOs: (i) the lack of appropriate financial support and/or incentives for the development and implementation of energy efficiency projects; (ii) industrial enterprises have low interest in energy saving and energy efficiency; and (iii) the lack of a legal framework, especially for regulating energy performance contracting for sharing EE results between ESCOs and enterprises.

The lack of experts in ESCOs is also a barrier to the development of ESCOs in Viet Nam. The number of professionally trained and highly specialized experts is limited that lessens the effectiveness of evaluation, feasibility studies, and accurate calculation of benefits as deciding whether ESCOs should invest in an EE project. Therefore, to reach a mature ESCO business ecosystem, addressing professionals and expertise in this field is important in the coming years.

Unless practical and viable measures to address those existing barriers are carefully designed and implemented, market failure would persist, and unlocking the energy-saving potential in energy-intensive industries would not be scaled-up or at least would be delayed for a long time.

- *Lack of institutional champions due to the fragmented nature of EE measures with lacking an effective data collecting, monitoring, and evaluation system*

The EE regulatory framework and measures remain fragmented and lack institutional champions and accountability to enforce national-level EE goals. The objectives of EE policies and programs are not incorporated into specific sector master plans, which discourages the allocation of financial resources to achieve the expected results. Although the established mandatory reporting requirements, no established systems exist for monitoring and reporting on the achieved results of energy savings and emissions reduction that are vital to ensure those requirements to be compliant.

Energy and energy efficiency data are essential for the proper implementation of national energy governance through energy efficiency benchmarking activities at a nationwide level. An effective energy efficiency database will allow the government to analyze energy supply and demand that is required to set out indicative targets for environmental policy and energy efficiency policy. A database of energy consumption is especially helpful for energy consumption management; it plays an important role in estimating the potential of energy efficiency and conservation, evaluation of energy efficiency, and conservation. Monitoring and evaluation of energy data in Viet Nam are often only implemented as the requirements specified for distinct EE programs or projects funded by international donor agencies, therefore they are conducted on an ad hoc project-based basis. Most of the past and ongoing energy data collecting, monitoring, and evaluation activities are undertaken in the form of pre-EE implementation energy audits that aim at identifying EE potentials and measures. Although various EE measures have been implemented throughout the country, updated and post-implementation monitoring is still limited.

Currently, social and economic data including the energy sector are publicly disclosed by Viet Nam's General Statistics Office. However, the energy data and statistics have not acted as a quality input source for planning and forecasting pertaining to energy consumption and supply for the sector and overall the country; as well as serving other energy efficiency potential measuring or monitoring. Moreover, the lack of an organization or agency that is officially responsible for data collection and making a database on energy efficiency results in fragmented data collection and management. Not having a solid energy efficiency database challenges the adoption of market-based instruments for EE in the future in Viet Nam when discouraging energy-saving monitoring and evaluation effectively.

13.5 Conclusion and Policy Recommendations

Energy conservation is one of the effective measures to save natural resources and to reduce CO_2 emissions to help achieve and surpass the international commitments in greening the economy with low carbon emissions adoption, particularly in emerging and industrializing countries such as Viet Nam. However, finding an appropriate financing source for the initial investment of energy-efficient measures is the hurdle to promote energy saving in the country with high-efficiency equipment is costly and with little market competitiveness for such equipment. Given those conditions, incentive mechanisms are necessary to facilitate the introduction and development of EE measures. The current available financial mechanisms to streamline energy saving are identified and employed with most coming from the state budget and international development donors with lower interest and other preferential conditions in tenure and collateral.

Thus far, most of the financing for EE projects in Viet Nam have been in the form of development assistance focused on providing technology in demonstration projects, and usually initiated and managed by the government or external donor programs. To scale-up financing EE with more participation from private investment, fundamental and sustainable remedies should be addressed.

Reviewing Energy Pricing

Energy pricing is a driving force on consumer attitudes, behavior, and motivation toward saving energy and will be a deciding factor determining the scale and size of Viet Nam's future energy efficiency improvement. The People's Republic of China (PRC) has a successful case in adjusting electricity prices contributing to the energy efficiency policy implementation of the government. From the mid 1980s, the PRC government began to adjust the energy price gradually and employed the dual pricing system after practising a heavily distorted energy price that resulted in weak motivation to save energy for energy-end users. By the mid 1990s, the PRC's energy price had been brought close to market orientation and international levels that generated a stronger motivation for enterprises and individuals to focus on energy cost and greatly stimulated energy efficiency in the PRC.

As for Viet Nam, special focus needs to be devoted to amending the pricing policies for electricity and other energy use to encourage improved energy efficiency without undermining industrial competitiveness or creating social hardship for marginalized groups. Also, the electricity price policy for energy-intensive industries should be shifted from helping the enterprises enhance their competitiveness by cheap electricity costs to incentivizing them through better energy efficiency adoptions and investment.

Applying Different Types of EE Investment Incentives to Address the High Up-Front Cost Barriers to Industrial Sector, Particularly the Industrial SMEs

SMEs play a crucial role in the Viet Nam's economy. According to the statistics of the Association of Small and Medium Enterprises, Viet Nam has nearly 600,000 SMEs, accounting for about 97.5% of the total number of actual businesses operating. The total registered capital of SMEs is approximately $121 billion, making up 30% of the total registered capital of enterprises. SMEs contribute about 40% of the GDP; 30% of the state budget, 33% of the value of industrial output, 30% of the value of export goods, and create nearly 60% of employment in the economy. SMEs are considered to be the engine and driving force of economic growth in Viet Nam. At the same time, this sector is one of the largest energy consumers.

In 2018, SMEs used large amounts of energy with 23.5 billion toe, making up 43% of total consumption in the country. In terms of energy efficiency, up to the present, only 14% of enterprises in the processing industry were surveyed with technology of less than 3 years, while 53% had technology from 6 years or more due to limited capital and resources. The efficient use of energy in Viet Nam is still inadequate, especially in the SME sector.

The lack of EE adoption motivation from SME energy end users is understandable when they decide to invest in new manufacturing facilities. Many factors are in careful consideration pertaining to technology, design, or productivity under a budget constraint. Thus, energy efficiency is only one considered criteria and often less weighted among others. The solution for authorities in this case is to intervene in the technology selection decisions of SME investors and motivate them to implement energy efficient solutions.

Given the fact that SMEs consume a large proportion of total energy in the economy but witness barriers in accessing finance including financing for EE adoption, a special credit or financing program should be considered to apply exclusively for SMEs.

On the banking sector side, only a few local financial institutions have dedicated energy efficiency lending as part of their green financing business line, which makes up only a small fraction of the loan portfolio. Most of the existing energy efficiency lending is focused on a small number of large industrial companies with high creditworthiness. At the same time, many industrial enterprises and ESCOs do not have the same level of creditworthiness or collateral resources as the larger firms, and therefore have limited access to capital from the local banking sector. Commercial financiers also have little incentive to provide long-term loans given the prevailing term structure of interest rates in Viet Nam, which does not provide banks with much additional margin for longer tenors. Besides, many local banks lack experience and capacity to appraise energy efficiency investments or have a high-risk perception of such investments, limiting opportunities to unlock the energy conservation and climate mitigation potential of the industrial sector, particularly in SMEs. Considering the various constraints together, local banks are currently not incentivized to expand their lending for energy efficiency purposes.

Given the high value of the upfront cost of EE technologies and equipment and difficulty in access bank loans, EE policies focusing on the SME sector should be direct subsidies or rebates and buy-down incentives. These will help lessen the burden in upfront cost investment and get SMEs more motivated in transforming energy use by EE technologies.

Unleashing Market Forces to Start Creating an Enabling Environment for Adopting Market-Based Mechanisms for Energy Efficiency

While regulations and fiscal measures are important for drawing attention to energy waste, ensuring information asymmetry avoidance, and overcoming certain specific market failures, the use of market forces is critical for nurturing large-scale, efficient, and sustainable investment in more efficient energy-use systems.

An effective energy efficiency investment ecosystem is not likely to develop without initial government intervention and encouragement. However, given the large scale of investment potential in Viet Nam, reliance on market-based mechanisms (MBM) is essential to achieving long-term and sustainable energy-efficiency goals.

A number of economies across Asia such as Taipei,China and the Republic of Korea are implementing MBMs to tackle energy–climate relation issues including EE, in which the energy efficiency standard is a major MBM type (USAID 2019).

Currently, Viet Nam has not yet deployed MBMs in energy efficiency due to lacking fundamental conditions to implement such vehicles. To create an enabling environment for MBM adoption in the future, a few preparatory activities have been started with the support of international donors, including regulating minimum energy performance standards in chemical production, iron and steel, pulp and paper, plastic, beverage, seafood processing, sugar cane, and cement production. The World Bank (2020) has been planning to help the government of to establish the first-ever MBM through its Vietnam Energy Efficiency Carbon Crediting Program.

MBMs provide flexibility for participants to select the most cost-effective mitigation solution by using market forces rather than a top-down policy of prescribed approaches. This flexibility also encourages innovation in mitigation solutions as regulated entities strive to meet targets more efficiently. To encourage energy efficiency by adopting MBMs in Viet Nam, and to enhance minimum energy efficiency performance standards in energy-intensive industries, energy audits play an important role.

It can be said that given the current situation of insufficient EE investment in Viet Nam is a result of the limited information available on specific energy consumption data and a lack of knowledge of the technical solutions available. Energy audits are a key solution to deal with the above-mentioned issues when using technical and economic measures to evaluate the status of energy use to realize and suggest the practical energy saving options to reduce energy cost and increase energy effectiveness.

Improving Energy Efficiency Data Monitoring and Evaluation
Viet Nam should establish an energy database center, including an energy efficiency datahub, to encourage the collection of data required for establishing energy efficiency indicators and monitoring processes in energy efficiency implementation in different levels from enterprises to local and national levels. Furthermore, an energy efficiency data and monitoring system covering all sectors including decisions on financing should be established to overcome the lack of end user data at the subsector scale. There is also a need to designate major industries for the designated statistics on energy and legally oblige them to report, based on the Law of Energy Efficiency or the Law on Statistics. Moreover, it is beneficial to use the support of international partners from providing technical assistance to establish the processing and procedure of energy efficiency statistics; developing an infrastructure for monitoring energy consumption and evaluating efficiency performance in key energy-intensive sectors and end users, thus helping the government design well-targeted policy interventions and being able to track and evaluate the progress.

Enhancing the Regulatory Environment for ESCO Development
In the case of Viet Nam where ESCOs are in the early phase of development, establishing a policy-driven ESCO market is essential to nurture this type of busines rather than implementing a market-driven environment that is only suitable if it evolves to a matured phase. Preferential regulations are critical in stimulating the uptake of the ESCO model in Viet Nam with strong guidance and regulation to the market. In fact, the ESCO market requires sufficient market drivers to be in places, such as access to finance, consistent EE standards in place, and a developed market of available ESCOs that are recognized and verified by the authorities.

Furthermore, in the long term, one of the means of providing capital liquidity for ESCOs or other holders of energy efficiency debt is the establishment of a secondary market for energy efficiency investment, whereby portfolios of loans or initially issued in a primary market can be pooled into a loan portfolio or tradable securities such as bonds or asset-backed securities. These in turn can be transacted in a secondary market that promotes liquidity by providing financiers an exit strategy and a transparent and reliable market price, thus increasing the number of lenders willing to participate in the EE market.

Investors in the EE segment include private capital sources of pension funds, insurance companies, or private equity. One example of a successful operation of the secondary market transaction model is Bulgaria's Energetics and Energy Savings Fund that acts as a secondary buyer of future receivables from EPCs of ESCOs. This financing model allows ESCOs to free up their balance sheet to be able to develop and fund new projects or pipelines.

Although the ESCO market for energy efficiency financing is at the very early stage of development and market uptake for energy efficiency projects is constrained by low demand for energy efficiency project pipelines, and consequently limited appetite to finance such projects in Viet Nam, however, the government should consider during their process of preparing a legal framework and policy for ESCOs model. To reach the necessary scale and meet the policy targets, the development of secondary markets is imminent to finance energy efficiency at scale.

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