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Editors

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Foreword

Recognizing climate change as one of the biggest threats we face, the Government of Indonesia has made several important contributions to addressing this issue. In 2007, we hosted the 13th Conference of the Parties to the United Nations Framework Convention on Climate Change in Bali. In 2009, the government announced a voluntary commitment to reduce its greenhouse gas emissions by 26 % below a business-as-usual scenario by 2020 using domestic resources and up to 41 % with international support. This was followed by the formulation and implementation of national and regional mitigation action plans. Indonesia is also accelerating adaptation efforts, as it is vulnerable to the impacts of climate change, such as the sea level rise and a change in the rainfall pattern. In this regard, the national adaptation action plan was officially launched in 2014. The Ministry of National Development Planning/National Development Planning Agency (BAPPENAS) has been coordinating with relevant line ministries and local governments for the implementation of these planned actions. We have integrated climate change mitigation and adaptation into the Medium-Term Development Plan. The Japan International Cooperation Agency (JICA) under the Project of "Capacity Development for Climate Change Strategies in Indonesia" has supported the mainstreaming process.

As part of the climate change mitigation and adaptation implementation plan, Indonesia recognizes the importance of human capacity. Therefore, human resource development is one of the important components of the above project, under which some young officials from Indonesia had opportunities to study at Hiroshima University, Japan. Contributions were made to this publication by those officials and professors at the university as well as experts of JICA, among others. The chapters in this publication present recent developments on climate change policy in Indonesia. The book also provides a collection of chapters that address the complexity of the relationship between climate and development policies in a range of sectors in Indonesia.

I would like to convey our gratitude to Professor Shinji Kaneko at the Graduate School for International Development and Cooperation of Hiroshima University, who has guided our young officials in completing their research works. Our sincere appreciation is also extended to Professor Akimasa Fujiwara, the Dean of the Graduate School. I wish to convey our many thanks to JICA. I hope that this book will contribute to better understanding and further discussion of the complex issues of climate and development.

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Preface

Background and Objective of the Book

The relationship between climate change and sustainable development has been a long-standing issue among researchers and practitioners. It was also considered at the latest assessment report of the Intergovernmental Panel on Climate Change (IPCC). The climate and development nexus is complex. While development policy regulates carbon emission paths, the resulting change in climate constrains possible development paths. While climate change mitigation and adaptation actions can alleviate negative effects on development, many of the determinants for the mitigative and adaptive capacities are shaped by the level of development. As capacities for effective climate actions have strong overlap with those for sustainable development, synergies and co-benefits exist between the two. There are potential trade-offs, however, since some climate responses may draw resources away from other developmental priorities, impose limitations on growth, or have adverse distributional effects. While the above findings are based on a high level of consensus among researchers, the latest IPCC report indicates that "the amount of supporting evidence is relatively limited as so many aspects of sustainable development and climate change mitigation and adaptation have yet to be experienced and studied empirically." Against this backdrop, this book provides empirical studies on the links between climate actions and development, using Indonesia as a case.

Indonesia has the second largest forest area in the world. It is one of the fastest-growing economies as well. According to the World Development Indicators, the population more than doubled and the real gross domestic product (GDP) increased by more than ten times during the period from 1965 to 2005. With a population of 240 million in 2010, Indonesia is the world's fourth most populous country after China, India, and the United States, and ranked at 16th in the world in terms of GDP. With this growth and scale, it also has become widely recognized as one of the largest greenhouse gas (GHG) emitters in the world. On the occasion of the G20 meeting in Pittsburgh (USA) in September 2009, the then Indonesian president announced a voluntary commitment to reduce its GHG emissions by 26 % by the year 2020 compared with the business-as-usual (BAU) level through its own national efforts and 41 % with international support. To follow this announcement, the National Action Plan for GHG Emission Reduction (*Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca*; RAN-GRK) was issued as Presidential Regulation number 61/2011 in September 2011 to provide a policy framework. In addition, Presidential Regulation number 71/2011 was issued for the purpose of regulating regular submission of national GHG inventory (Chap. 2, this volume).

Indonesia is also prone to the impacts of climate variability and change. According to the latest National Communication of Indonesia, a substantial increase in temperatures, as well as a significant change in the volume and pattern of rainfall, has been observed across the country, and a number of climate models agree that these trends are projected to continue or even accelerate in the future. In response, the National Action Plan for Climate Change Adaptation (*Rencana Aksi Nasional untuk Adaptasi Perubahan Iklim*, RAN-API) was developed and officially launched in February 2014 with the aim of providing directions for mainstreaming climate change adaptation into national, local, and sectoral development planning (Chap. 4, this volume).

Indonesia has thus been making efforts to reconcile sustainable development and climate change policy. In this process, trade-offs as well as synergies between the two have been faced. Forest areas are where such conflicts are visible, with competing interests of oil palm plantations, mineral development, forest conservation, and the welfare of those who live there, among others (Chaps. 5 and 6, this volume). Energy subsidy is another example of controversy, with a potential to substantially and simultaneously affect the carbon emission paths, economic growth, and distribution between the rich and the poor (Chap. 7, this volume). This book compiles empirical studies on these and other similarly contentious issues, based on the experiences in Indonesia, as one of the most proactive on climate policy among developing countries. While it is mainly intended for practitioners, the editors hope that it will be also useful for researchers and students.

The plan to publish this book originated from the collaboration between Hiroshima University and the project "Capacity Development for Climate Change Strategies in Indonesia" of the Japan International Cooperation Agency (JICA). This project has been in operation since October 2010 to support the government of Indonesia in enhancing its capacity to tackle climate change. Under the project, some officials of the Indonesian government were provided with opportunities to study at Japanese universities, including Hiroshima University. Contributions to this book were made by those who received funding to study at the university, as well as JICA experts of the Project and other researchers in and outside Indonesia.

At the time of this writing, the new administration under President Joko Widodo has been established, with a mixture of continuity and change in policies relating to climate and development. The new president launched the National Mid-term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional*, RPJMN) for 2015–2019, which retained both RAN-GRK and RAN-API. In the meantime, he issued a regulation concerning the merger of two formerly separate ministries to form the Ministry of Environment and Forestry. At the same time, he ordered the integration of the duties and functions of the REDD+ Agency and the National Council on Climate Change, both of which had been established under the previous administration, into the newly formed ministry. These recent institutional changes have not yet been reflected in some of the following chapters. Reconciliation of sustainable development and climate policy, however, will continue to be a challenge in Indonesia, and this is also the case for many other countries.

Outline of the Book

This book consists of two parts. Part I, from Chaps. 1, 2, 3 and 4, provides an introduction to climate change policies and institutions in Indonesia. While Chap. 1 reviews the economic development and carbon emission path in Indonesia, Chaps. 2, 3 and 4 address the climate change mitigation and adaptation policies. Kaneko (Chap. 1) provides an overview of the economic growth and trade, energy supply and demand, deforestation, and GHG emissions in Indonesia since 1990. The author employs a preliminary decomposition analysis of the energy-related CO_2 emissions over the last 40 years with data from the International Energy Agency (IEA).

Morizane, Enoki, Hase, and Setiawan (Chap. 2) introduce climate change mitigation policies and institutions in Indonesia. This chapter is descriptive in nature, but it has a comprehensive coverage of the relevant topics, such as GHG emissions status and trends; RAN-GRK and other mitigation-related initiatives, including those related to "reducing emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks (REDD+)"; institutional arrangements; and international cooperation, and funding mechanisms, including the Joint Crediting Mechanism (JCM).

Based on the results of a field survey, Ueda and Matsuoka (Chap. 3) demonstrate the scale of apparent changes in emission figures which may result from pure methodological improvement for GHG inventory preparation, not from actual mitigation actions. The implication of the apparent changes on policy formulation and evaluation is also discussed. The difficulty in establishing appropriate data and its policy implication is also addressed in Chap. 9.

Consideration of the monitoring and evaluation of climate change adaptation has expanded significantly in recent years among both researchers and practitioners. In Chap. 4, Kawanishi, Preston, and Ridwan evaluate national adaptation planning, using RAN-API as a case. The criteria and scoring system, developed by prior research, are applied to evaluate RAN-API, both as identified in its document and as viewed by stakeholders. A desktop review and questionnaires were undertaken to this end. This chapter also provides an overview of the climate variability, change, and impacts in Indonesia.

Part II is a collection of chapters that address climate change sectoral challenges. Chapters 5, 6, 7, 8, 9, 10, 11 and 12 address sectoral mitigation actions in Indonesia, analyzing their synergies and conflicts with development in Indonesia. The sectors were selected on the basis of their significance in the national economy and GHG emissions. Chapters 13 and 14, on the other hand, address climate impacts on rice production and response measures in Indonesia. Rice, the staple food of the country, is chosen because of its significance in national food security and rural development.

Chapters 5 and 6 address forestry and peatland, the largest sources of carbon emissions in Indonesia. In Chap. 5, Indarto analyzes the relationship between forest concessions and deforestation. After examining the role of various types of forest concessions, the author reveals that some types of concessions significantly contribute to deforestation. Quantitative analyses with official data at the provincial level are employed. With this result, the chapter discusses some implications on the current forest moratorium policy and proposes alternative ways to issue forest concessions, such as auction.

Yamamoto and Takeuchi (Chap. 6) discuss prevention of peatland fire as a part of REDD+. With Central Kalimantan as a study location, where peatland fire significantly contributes to the release of large amounts of carbon, the authors find that economic factors, such as the value of labor allocation for rubber production, and non-economic factors, such as traditional mutual assistance, can promote fire prevention, suggesting the necessity of a combination of economic and non-economic incentives for the effective implementation of REDD+.

The following two chapters address the energy issue. With a growing economy and increasing population, Indonesia has become a significant energy user as well as a net importer of oil. The oil subsidy, which accounts for one-fifth of the fiscal expenditure of the government, has been the source of a long-running controversy with high political stakes. In Chap. 7, Luthfi and Kaneko analyze the net impacts of international oil prices on the macro-economy of the country. The authors also assess the effects of the removal of the oil subsidy as climate change mitigation.

"Integrated Indonesian Energy and Environment Modeling" has been conducted by the Indonesian Institute for Energy Economics (IIEE) to support BAPPENAS in the formulation of the National Mid-term Development Plan for 2015–2019. In Chap. 8, Siahaan, Fitri, and Batih introduce the modeling results with particular attention to the energy mix in the power sector and its associated GHG emissions.

Armundito and Kaneko (Chap. 9) discuss environmental productivities and carbon abatement costs of manufacturing sectors. The chapter provides a review of the changes over the last 20 years in energy efficiency and carbon intensity of the manufacturing sector, and discusses the marginal abatement cost of CO_2 emissions. With firm-level data, the authors discuss the possible financial burdens for firms in different sectors in case carbon regulations are introduced.

In Chap. 10, Ghozali and Kaneko cover consumer behavior and eco-labeling. The chapter examines air conditioners, one of the fastest-growing home appliances in the market, which consume large amounts of electricity, without energy efficiency-labeling available yet. With data from an interview survey on consumer preferences in greater Jakarta, the chapter analyzes possible purchasing behavior changes of urban consumers in response to a hypothetical case where an authorized energy efficiency-labeling scheme is introduced.

The transport sector is the focus of Chap. 11. Mass Rapid Transit (MRT), under construction in Jakarta, is expected to mitigate traffic congestion and the associated GHG emissions. Using a consumer survey, Maimunah and Kaneko discuss the climate change mitigation effect of a possible modal shift from passenger vehicles and motorcycles to MRT and compare it with the potential impacts of other policies, such as road pricing under the Ministry of Transportation, fuel pricing under the Ministry of Energy and Mineral Resources, and tax reduction for compact cars under the Ministry of Industry.

The utilization of waste-to-energy (WTE) technologies is a long-standing strategy in developed countries in achieving the simultaneous objectives of sustainable waste management, reduction of GHG emissions, and development of energy from renewable sources. Previous studies, however, have dismissed such solutions for developing countries because of high costs, unsuitable wastes and climate, and inadequate human resources. New WTE technologies were developed that better fit tropical environments and waste with greater moisture and organic content. In Chap. 12, Johnson evaluates the feasibility of these adapted WTE projects and presents an accounting of the economic and environmental costs and benefits, using Bekasi municipality near Jakarta as a study location.

Chapters 13 and 14 shift their attention to climate impacts and responses in rice production in Indonesia. Anggarendra, Guritno, and Singh (Chap. 13) describe the "Integrated Cropping Calendar System (KATAM)" as a tool to provide climate information to farmers. In reference to the previous studies which indicate a capacity of information intermediaries and the extent of interaction as the factors that affect the use of climate information, this chapter also describes the status of agricultural extension workers and the "Climate Field School" as the government initiative to promote two-way communication.

Insurance is stipulated in Article 4.8 of the UNFCCC as one of the necessary actions "to meet specific needs and concerns of the developing country parties arising from the adverse effects of climate change." In recent years, increasing importance has been attached to risk management and insurance in international negotiations on climate change adaptation. In Chap. 14, Pasaribu and Sudiyanto present opportunities and challenges of crop insurance as one of the risk management instruments for rice farmers under a changing climate, based on the lessons learned from the pilot insurance provided by the government of Indonesia.

Hiroshima, Japan — Shinji Kaneko
Tokyo, Japan — Masato Kawanishi

Contents

Part I
Climate Change, Policies, and Institutions

Chapter 1
Economy, Energy, and CO_2 Emissions

Shinji Kaneko

Abstract The introductory chapter provides a historical overview on the nexus of economic development, energy use, and energy-related CO_2 emissions over the past 40 years in Indonesia. A logarithmic mean Divisia index (LMDI) decomposition analysis was employed to examine determinants for the changes in energy-related CO_2 emissions. The 40-year period was divided into three major periods of political regimes with available data: 1971–1997 for the Suharto regime, 1999–2004 for the transition to a democratic regime, and 2005–2011 for the Yudhoyono regime. The analysis found that (1) coal started to play an important role in exports and power generation, which have positive effects on CO_2 emissions; (2) the price of oil commodities increased due to the fuel subsidy removal, and the rise of international oil prices accelerated improvements in energy efficiency; and (3) the transportation sector became increasingly important to increasing CO_2 emissions. The chapter concludes with future perspectives related to other chapters in the book.

Keywords Economic growth • Energy-related CO_2 emissions • Decomposition analysis • LMDI

1.1 Introduction

The Suharto regime began in 1966 and successfully developed a national economy with an average GDP growth rate at 7.18 % for almost 30 years until the Asian financial crisis hit the country. The GDP per capita significantly increased from 280 US$ in 1966 to 1235 US$ in 1997. With rich natural resources and a large population with a relatively young demographic structure, the country was expected to continue to experience rapid economic growth before the financial crisis. The well-known report of the World Bank, East Asian Miracle (1994), included Indonesia as a highly performing Asian economy (HPAE), together with Japan, Korea, Taiwan, Hong Kong, Singapore, Malaysia, and Thailand. In 1998,

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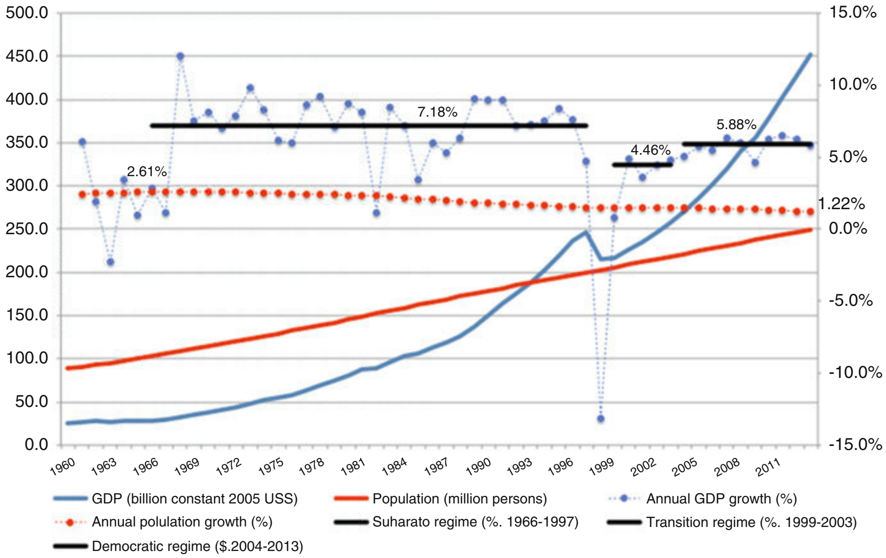

Fig. 1.1 GDP and population in Indonesia from 1960 to 2013 (Source: World Development Indicator)

Indonesia experienced an extremely serious economic crisis affected by the Asian financial crisis, which dropped its GDP growth to a large negative rate at −13.1 % (Fig. 1.1). As a result, the Suharto regime collapsed in May 1998, and Indonesia entered the political regime transition period from a developmental dictatorship to a democratic regime until 2004, when President Susilo Bambang Yudhoyono was elected. During the 6-year transition and economic recovery period after the Asian financial crisis, the country experienced much turbulence and many changes, which were evident by three different presidents and four revisions of the national constitution; however, there was steady progress toward ensuring freedom and human rights in the democratic regime. During the same period, a drastic decentralization policy was also introduced. The average GDP growth rate during the transition period was 4.46 %, which is almost two thirds of the average economic growth of the Suharto regime.

The 10 years of the Yudhoyono regime, from 2004 to 2014, demonstrated relatively steady economic growth, with an average GDP growth rate of 5.88 %. The figure was slightly lower than 6 %, which is an important economic growth target for Indonesia to annually absorb new and young laborers in order to maintain a low unemployment rate. During the Yudhoyono regime, several progresses and achievements were made toward law and order stability, anti-terrorism, anti-corruption, and improving the decentralization policy. It is worth noting that a symbolic achievement was the peace talks with the Aceh state after the earthquake and tsunami in December 2004. Since its national independence from the Dutch colonial period, regional independence movements have long been an important political agenda in Indonesia. The drastic 2001 decentralization that transferred the administrative authorities beyond state governments directly to provincial and city governments was modified in 2004 due to concerns of regional independence. The vertical hierarchy then resumed functioning. It was also during the Yudhoyono regime when Indonesia hosted COP13 of UNFCCC in Bali Island and established the Bali Action Plan in 2007.

As the fourth most populous country in the world after the United States, Indonesia's population is currently approximately 250 million. Since 1960, when the population was 89 million, the population has almost linearly grown, with average growth rate of 2.0 %. The annual growth rate peaked around the late 1960s at 2.61 % and gradually declined to 1.22 % as of 2013. However, Indonesia is still in the declining phase for the demographic-dependent ratio, and the number of productive laborers is predicted to increase until the mid-2020s (United Nations 2015).

Considering the historical economic development of Indonesia in terms of export performance, a structural change of economic development can be observed (Fig. 1.2). Before the Suharto regime, which began in 1962, export commodities mainly consisted of four categories: agricultural raw materials (45.6 %), fuels (31.7 %), food (16.8 %), and ores and metals (5.6 %), which are all from primary industries. In the first half of the Suharto regime, between 1966 and mid-1982, the share of agricultural raw materials significantly decreased to 5.8 %, while fuel (mineral oil and gas) shares expanded to 82.4 %, which shows that the economic development during the first half of the Suharto regime was largely driven by international sales of mineral oil and gas. There was the shift to industrialization in the mid-1980s. Consequently, the share of exports of non-high-tech

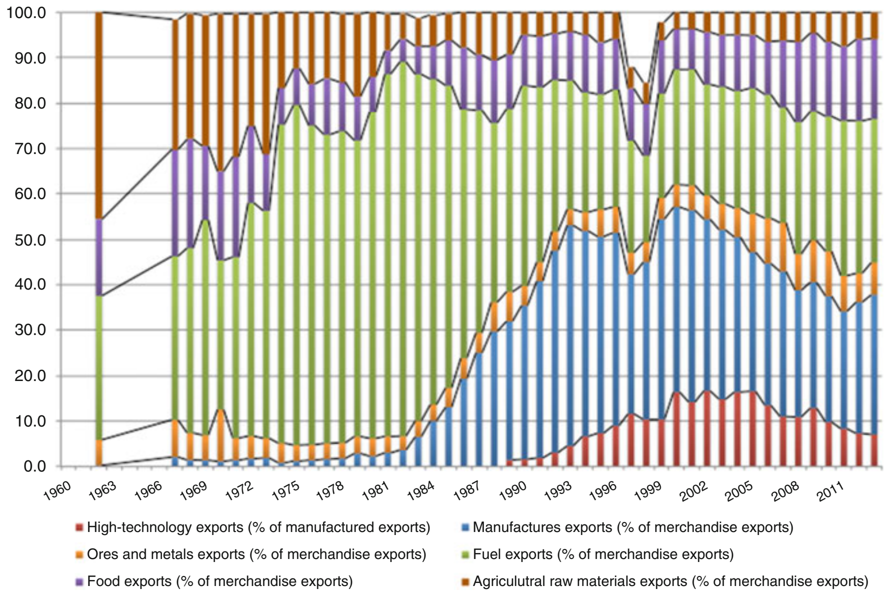

Fig. 1.2 Structural change in the merchandise exports of Indonesia from 1960 to 2013 (Source: World Development Indicator)

manufacturing commodities sharply expanded from 3.6 % in 1982 to 48.5 % in 1993, whereas the dependency on fuel exports dramatically decreased to 28.4 %. At the same time, the development of the high-tech manufacturing industry and its export began in 1989. The share of high-tech manufacturing exports increased thereafter, reaching more than 16 % four different times: in 2000, 2002, 2004, and 2005. One can observe that manufacturing exports drove the economy during the second half of the Suharto regime.

The manufacturing sector in Indonesia, including both non-high-tech and high-tech industries, continuously grew, except during the Asian financial crisis period, until 2000, reaching 57.1 %, which has been the highest value since that period. Instead, conventional commodities, including agricultural raw materials, food, fuels, and ores and metals, from the primary industry, started to expand their shares during the recent democratic period of Yudhoyono, even though Indonesia has become a net oil-importing country since 2004, as discussed later. Therefore, there is present concern about future sustainable economic development, in terms of environmental conservation and unemployment, if the dependency on the primary industry for exports continues.

Crude oil, one of the sources of economic growth in Indonesia, particularly in the first half of the Suharto regime, has declined in production since the late 1990s. Figure 1.3 compares the production energy values and exports of three major fossil fuels in Indonesia. One common feature is that the majority of energy produced in the country is exported, which is particularly true for coal. The other observation is the transitional shift in the production of fossil fuels around the late 1990s. While

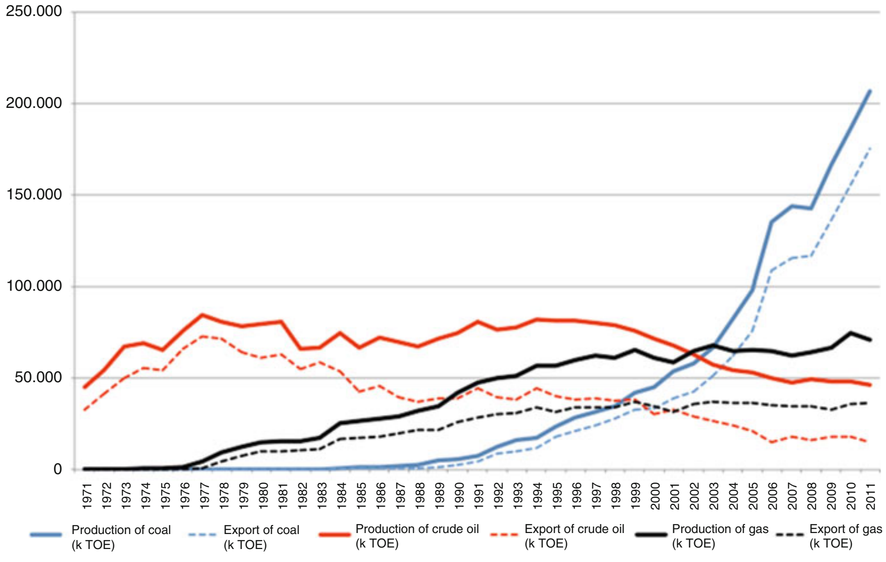

Fig. 1.3 Energy values of the production and export of coal, crude oil, and natural gas in Indonesia (Source: IEA/OECD (2013))

the production of crude oil declined, as mentioned above, coal production sharply increased, and natural gas production demonstrated a modest increase since 2000. The peak of crude oil exports occurred in 1977. Currently, the energy value of coal production is four times and three times larger than those of crude oil and natural gas, respectively. The economic implication for this shift is derived from the difference in economic values of those fossil fuels, where prices of crude oil and natural gas are relatively higher than that of coal. The environmental implication for this shift is derived from the difference in emission factors of carbon and other local pollutants, where natural gas is much cleaner than coal.

The domestic supply of energy is intertwined with the domestic production of fossil fuels. Figure 1.4 shows the historical trajectory of the total primary energy supply in Indonesia between 1971 and 2011. Approximately 35 million TOE was supplied to Indonesia in 1971: three quarters were in the form of traditional biomass, and the rest was crude oil. Since then, the primary energy supply increased by six times, reaching 200 million TOE in 2011. For the two major energies supplied in 1971, crude oil increased until the late 1990s, whereas traditional biomass continued to slowly grow until now, doubling from 1971 to 2011. Several new sources of energy appeared in the trajectory at different points in time: natural gas in the 1980s, coal in the 1990s, and hydropower and geothermal energy in the 2000s. Since the early 2000s, along with the transition to a net oil-importing country, refined petroleum products have been included in the primary energy supply and are imported mainly from Singapore. The recent rapid growth in coal production, which is mostly exported, began to be used for the domestic energy supply. As a consequence, the

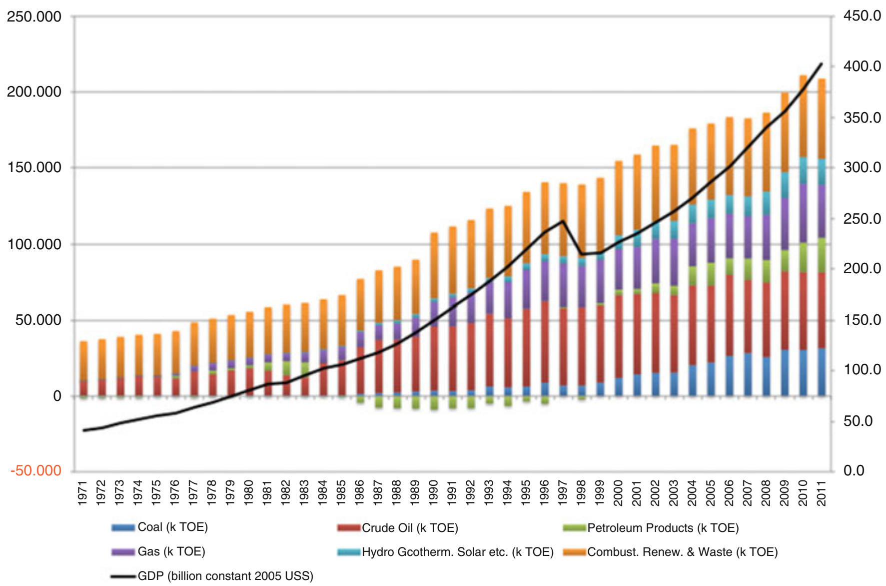

Fig. 1.4 Historical trajectory of the total primary energy supply in Indonesia (Source: IEA/OECD (2013); note: GDP is displayed in right axis)

current energy supply structure of Indonesia is diversified into six sources, although traditional biomass and crude oil are still the largest energy sources.

Passing through the energy transformation sectors of Indonesia, the primary supply energies are used either directly or in different forms of secondary energy. Because there are transformation and distribution losses, the amount of energy actually used is less than that of the primary supply. In 1971, 32 million TOE was used, and less than 10 % of the primary supply was lost, whereas in 2011, 158 million TOE was used, and nearly 20 % of the primary supply was lost (Fig. 1.5). The dominance of traditional biomass is apparent, as the energy loss from transformation and distribution was very limited. Two major energy categories were dominant in the final energy consumption: traditional biomass and petroleum products. Although traditional biomass lost and petroleum products gained in their individual shares, together, the combined share declined from 98.9 % in 1971 to 72.6 % in 2011. In 2008, the share of petroleum products surpassed that of traditional biomass for the first time in Indonesia's history. Three forms of energy have filled the remaining share: coal, natural gas, and electricity. It should be noted that despite the steady increase of the share of electricity in the final energy consumption, it began at less than 1 % during the 1970s and was only 8.7 % in 2011. The domestic use of coal and natural gas in industry is relatively recent (since the late 1990s), indicating that petroleum products, which have a labor-intensive input structure, have mostly driven the industrialization during the second half of the Suharto regime.

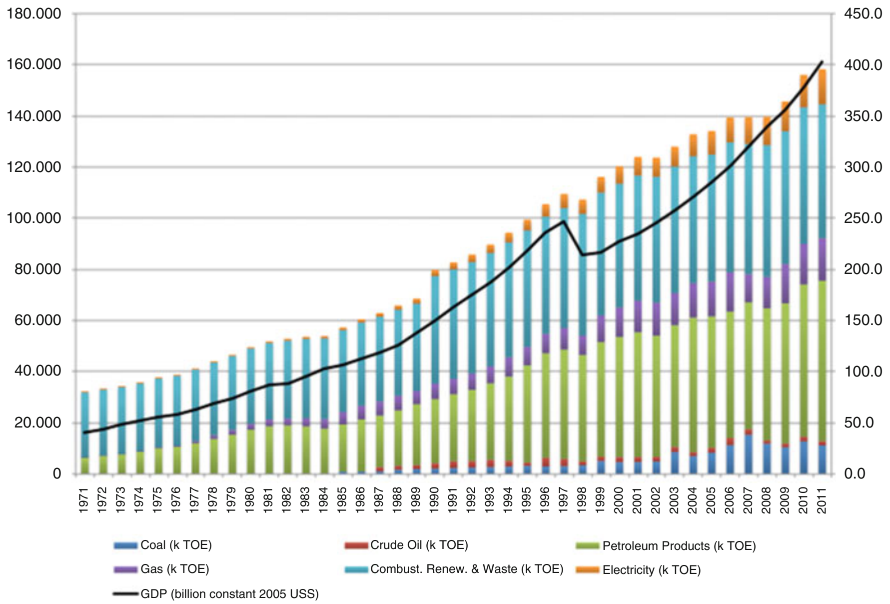

Fig. 1.5 Historical trajectory of final energy consumption by source in Indonesia (Source: IEA/OECD (2013), Note: GDP is displayed in right axis)

On the other side of the energy balance, Fig. 1.6 depicts historical changes in the demand structure by sector for energy uses as fuels, where nonenergy uses are excluded. Among others, the residential sector has been the dominant and largest energy-consuming sector, although its share has declined from 85.5 % in 1971 to 38.8 % in 2011. The start of the growth of the industrial sector in final energy consumption coincided with industrialization in the 1980s and continued until now. However, in recent years since 1999, the share of the industrial sector has remained at approximately 30 %, whereas the share of the transportation sector has grown from 18.1 % in 1999 to 26.4 % in 2011, and transportation has become a competitive sector with the industrial sector. The strong and robust demand for energy in the transportation sector is, in part, due to the successful development of the automobile and motorcycle manufacturing industry and to motorization. Considering that a large share of residential energy demand is supplied by traditional biomass and the share of commercial and public services is currently very limited, the future demand for electricity is expected to largely increase.

In Indonesia, the removal of energy subsidies was considered an extremely difficult political issue at the end of the Suharto regime and during the transition period between 1998 and 2003, with repeated withdrawals of government proposals due to strong resistance from energy users and the general public. Nevertheless, for the first time in the history of Indonesia, the policy was finally passed and put into action in March 2005. From this policy, Indonesia has already become a net oil-importing country; the demand for petroleum products has rapidly increased,

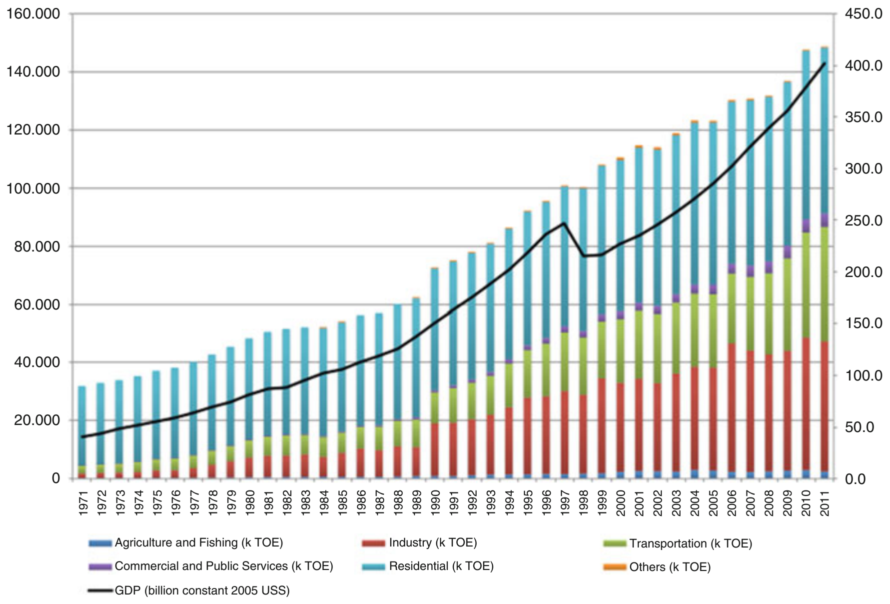

Fig. 1.6 Historical trajectory of final energy consumption by sector in Indonesia (Source: IEA/OECD (2013), Note: GDP is displayed in right axis)

and the international oil price has started to soar, remaining at a high price, which leads to a severe fiscal burden for the national budget. The increase in the international oil price brought additional revenue to Indonesia when the country was exporting crude oil. However, for an oil-importing country with energy subsidies, high international oil prices are extremely harmful to the national budget. Fortunately, during the democratic regime led by President Yudhoyono, with public trust and credibility, careful design, and a step-by-step and sector-by-sector phaseout strategy, the subsidy removal became a reality. The first step of this process was the removal of the energy subsidy in March 2005, when the international oil price increased to 40 US$, and kerosene use for residential needs was exempted. Then, the second step was in October 2005, when the international oil price reached 80 US $. The third step was in May 2008, followed by the fourth step in January 2013. In general, the first target of energy subsidy removal was industry and then the residential and transportation sectors. For the residential sector, the Zero Kero policy was implemented sequentially: its implementation started in Jakarta and then was spread to local cities, finally expanding to the entire country and promoting the shift of cooking fuel from kerosene to subsidized LPG. In 2015, the complete removal of the subsidy was implemented for regular gasoline.

Figure 1.7 compares the trade balance of oil commodities and macro energy efficiency. The net balance of trade for crude oil shows large surpluses and exports in the 1970s and 1980s. It started to decline in the 1990s and finally became negative (i.e., net import). While the net import of crude oil has been marginally limited, the net import of petroleum products has increased thereafter. Indonesia currently maintains a certain amount of crude oil exports, and it is known that sweet, higher-quality crude oil is exported due to contract restrictions and bitter, lower-quality crude oil is imported instead. Furthermore, refined petroleum products are much more costly than petroleum products domestically refined, which makes domestic prices of oil commodities expensive. Figure 1.7 also presents several macro indicators of energy efficiency, such as the total primary energy supply (TPES) per unit of GDP production (TPES/GDP), the total final energy consumption (TFEC) per unit of GDP production (TFEC/GDP), and the TFEC per unit of value added in the manufacturing sector (TFEC/GDP for manufacturing). While both TPES/GDP and TFEC/GDP steadily improved until the Asian financial crisis in 1997, TFEC/GDP for manufacturing fluctuated during that same period. After the crisis, TPES/GDP returned to the level in the early 1980s and took almost 10 years to recover to the level before the crisis. The gap between TPES/GDP and TFEC/GDP widened due to the gradual spread of secondary energy and the associated transformation losses. On the other hand, there has been no significant progress in energy efficiency in the manufacturing sector, despite the rise of energy costs due to energy subsidy reform and soaring international oil prices. This phenomenon could be explained by the shift from labor-intensive manufacturing industries to capital and energy-intensive ones.

As a result, energy-related CO_2 emissions largely increased over the past 40 years, which poses significant implications to the climate change mitigation policy of the country, though there are other important sources of greenhouse gas emissions, such as land use changes and peat fires. Figure 1.8 explains the available

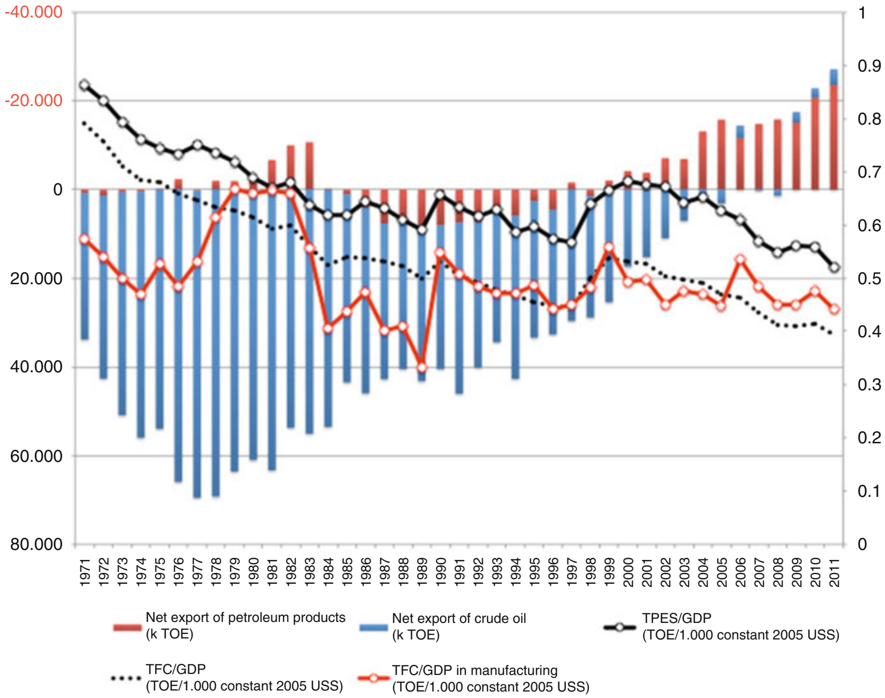

Fig. 1.7 Trade balance of oil commodities and macro energy efficiency (Source: World Development Indicator and IEA/OECD (2013))

estimates of energy-related CO_2 emissions in Indonesia that cover a sufficiently long term. One estimate was from the World Development Indicator, which contains an estimate of CO_2 emissions stemming from the burning of fossil fuels and the manufacturing of cement, compiled by the Oak Ridge National Laboratory, United States. The author computed the other two estimates with two simple accounting methods by applying the IEA/OECD publication on CO_2 emissions from fuel combustion to the energy balance tables for non-OECD countries provided by IEA/OECD. The emission factors used in these estimates were taken from the IPCC guideline on the GHG inventory in 2006. The first estimate corresponds to the reference approach, which uses primary energy supply data. The reference approach comprehensively captures the energy flow upstream but is unable to elucidate CO_2 emissions by sector. On the other hand, the second estimate corresponds to the sectoral approach, which uses final energy consumption data. Though the sectoral approach has the advantage of capturing CO_2 emissions by sector, indirect CO_2 emissions during the energy transformation process, such as conversion and distribution losses, are difficult to precisely and consistently compute. In addition, the sectoral approach in the present analysis does not consider nonenergy uses, while the reference approach does. These are two major possible causes of disparity between the reference approach and sectoral approach in Fig. 1.8.

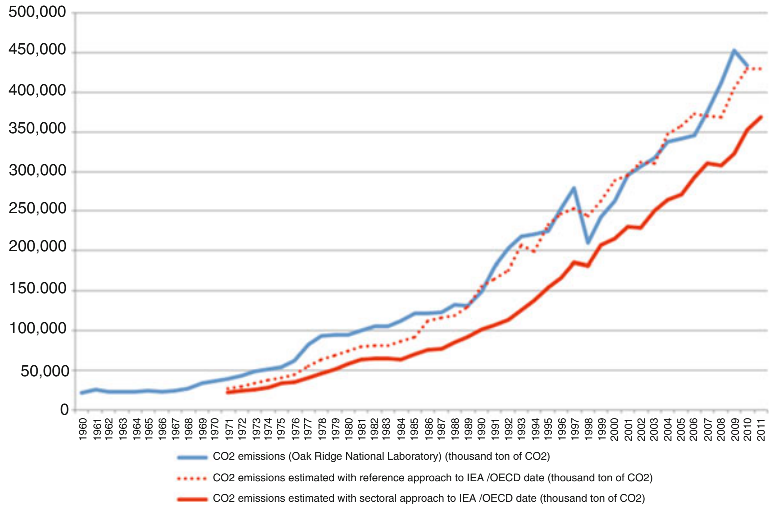

Fig. 1.8 Comparison of different estimates of energy-related CO_2 emissions in Indonesia (Source: World Development Indicator and IEA/OECD (2013))

Noncombustion emissions of CO_2 from cement production processes are considered to be negligible, as the scale of cement production in Indonesia is still small. Therefore, the disparity between the estimate by the Oak Ridge National Laboratory and that with the reference approach might be due to the level of breakdown of the energy sources. For example, the energy balance tables of IEA/OECD have aggregate energy values for petroleum products, while gasoline, diesel, kerosene, LPG, and other refined oil products are treated as similar energy sources with a common emission factor. The same approach is applied to coal-oriented energy sources. Considering this difference, these two estimates are in agreement, although the disparity between the two estimates is larger from 1971 to 1980. At the same time, the Oak Ridge National Laboratory estimate suggested a larger drop in energy consumption during the Asian financial crisis.

The increase in CO_2 emissions from 1971 to 2011 occurred much faster than that of energy use because the energy structure significantly changed to more carbon-intensive fossil fuels. The CO_2 emissions grew by more than 16 times over those 40 years, according to the author's estimates, whereas the total primary energy supply grew by six times, as mentioned earlier.

1.2 Method

Although large numbers of decomposition studies on energy and the environment have been reported, there is still a lack of accumulated empirical evidence in Indonesia. In this chapter, only highly aggregated levels of data are available for

Indonesia; the log mean Divisia index type I (LMDI-I) analysis, known as the "best" decomposition method, is conducted for Indonesia. The LMDI-I model has preferable attributes related to perfectness in terms of residual free and consistency in aggregation (Ang 2004).

1.2.1 Indicators and Data

The present study uses energy balance tables for Indonesia between 1971 and 2011 compiled by IEA/OECD (2013), the only publicly available and reliable data covering multiple years. The energy balance tables provide a matrix of 9 categories[1] of energy and 26 sectors of final consumers. Among the nine categories of energy, seven categories are used in Indonesia, except for nuclear and heat. For the final consumers, the 26 sectors – 13 subsectors of secondary industry, 8 subsectors of transportation, and 2 subsectors of primary industry, commercial and public services, residential, and nonspecified sector – are aggregated into 5 sectors[2] due to unavailability of consistent data.

From the energy balance tables with seven energy categories and five final consumption sectors, the energy consumption datasets by sector and by category over the 40 years are computed. Furthermore, with the carbon emission factors for coal, petroleum products, and natural gas taken from the IPCC guideline, corresponding datasets of CO_2 emissions by sector and by category over the 40 years are also computed. Note that for electricity, the information on the input and output structure of the sector for "electricity plants" is used to annually compute the CO_2 emissions per unit of electricity consumption.

The other data (the GDP in constant 2005 US$; the respective shares of primary, secondary, and tertiary sectors to GDP (%); the total population in millions; and the household final consumption expenditure in constant 2005 US$) are mostly taken from the World Development Indicators.[3] Data on the number of vehicles is available for the period between 2000 and 2011, and the data from 1971 to 2000 is supplemented by the data from the book compiled by the Japan Automobile Association. The number of vehicles includes not only privately owned passenger vehicles but also publicly owned passenger vehicles, trucks, and busses, while two wheelers are not included. Key variables are indexed to 1 in 1971 and compared in Fig. 1.9.

[1] (1) Coal, (2) crude oil, (3) petroleum products, (4) gas, (5) nuclear, (6) hydro, geothermal, solar, etc., (7) combust. renew. and waste, (8) electricity, and (9) heat.

[2] The "other miscellaneous sectors" are included in Commercial and Public Services.

[3] Household final consumption expenditure (formerly private consumption) is the market value of all goods and services, including durable products (such as cars, washing machines, and home computers) purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments separately and fees to governments in order to obtain permits and licenses. Here, household consumption expenditure includes the expenditures of nonprofit institutions serving households, even when reported by the country.

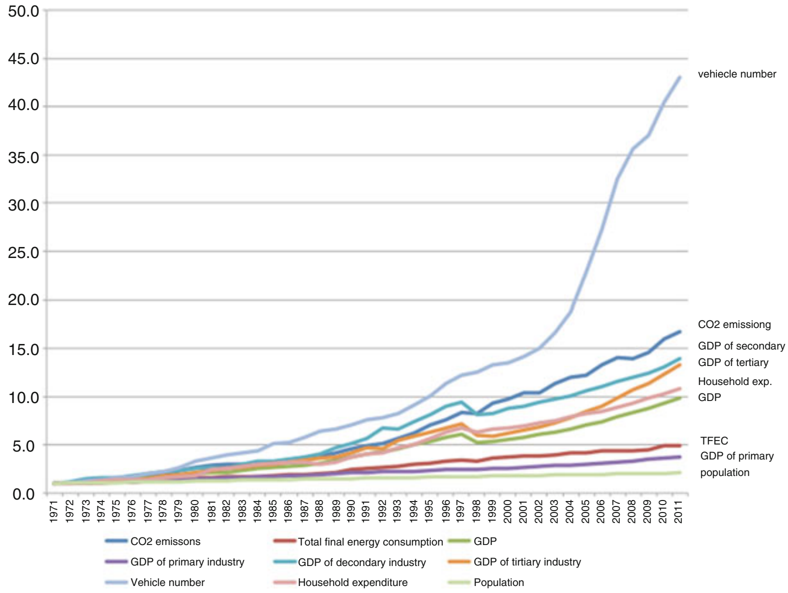

Fig. 1.9 Comparison of the key variables used for the decomposition analysis (Source: World Development Indicator and IEA/OECD (2013))

The vehicle number increased the most among these variables, followed by CO_2 emissions, and the GDP of the secondary industry. On the other hand, the population increased the least, followed by the GDP of the primary industry and the total primary energy consumption (TPEC).

1.2.2 Model

In the present analysis, total CO_2 emissions per year is calculated by the summation of 35 elements of CO_2 emissions, which are defined by 5 sectors and 7 energy categories in which each element is a product of predefined determinants. For the three production sectors, primary, secondary, and tertiary industries have six predefined determinants, whereas both the transportation sector and the residential sector each have five determinants, as seen in the following equations (Ang and Liu 2001).

$$CO_2 = \sum_{i=1}^{3}\sum_{j=1}^{7}\frac{CO_{2_{ij}}}{TFC_{ij}}\frac{TFC_{ij}}{TFC_i}\frac{TFC_i}{GDP_i}\frac{GDP_i}{GDP}\frac{GDP}{POP}POP$$

$$+\sum_{i=T}\sum_{j=1}^{7}\frac{CO_{2_{ij}}}{TFC_{ij}}\frac{TFC_{ij}}{TFC_i}\frac{TFC_i}{VN}\frac{VN}{POP}POP$$

$$+\sum_{i=H}\sum_{j=1}^{7}\frac{CO_{2_{ij}}}{TFC_{ij}}\frac{TFC_{ij}}{TFC_i}\frac{TFC_i}{HEP}\frac{HEP}{POP}POP$$

where CO_2 denotes total CO_2 emissions, and i and j represent the sector and energy category, respectively. While T and H represent the transportation sector and residential sector, respectively, the numbers from 1 to 3 for i denote the primary, secondary, and tertiary industry, respectively. TFC is the total final energy consumption, and VN and HEP denote vehicle number and total household expenditure, respectively. Finally, POP is the total population.

The first component on the right side of the above equation represents the CO_2 emission intensity from the use of the final energy in sector i for energy category j. The second component measures the structure of the energy categories for the total final energy consumption in sector i. The third component is the energy efficiency in reference to the scale of activities for each sector. In the production sectors, the respective value added is employed as a proxy for the scale of activities that demand energy. On the other hand, vehicle number and total household expenditures are used as the proxies for the scale of activities in the transportation and residential sectors, respectively. Due to data availability, the fourth component in the three production sectors captures the macro industrial structure. The transportation and residential sectors may be broken down to subsectors of activities, such as different transportation modes or the difference between passenger and freight transport for the transportation sector and urban and rural households or different social groups of households for the residential sector. However, due to data limitations, the present analysis does not include the structural component of energy-demanding activities in the transportation and residential sectors. The last two components, the per capita activity levels and the population, in all five sectors, are added.

With the use of indices, the aforementioned equation is converted to

$$CO_2 = \sum_{i=1}^{3}\sum_{j=1}^{7} CI_{ij}\,ENS_{ij}\,ENE_i\,ECS_i\,INC\,POP$$

$$+\sum_{i=T}\sum_{j=1}^{7} CI_{ij}\,ENS_{ij}\,ENE_i\,VI\,POP$$

$$+\sum_{i=H}\sum_{j=1}^{7} CI_{ij}\,ENS_{ij}\,ENE_i\,HI\,POP$$

By taking the logarithmic differentiation with respect to time *t*, the following differential equation is derived:

$$
\begin{aligned}
&\frac{d\mathrm{lnCO_2}}{dt}\\
&= \sum_{i=1}^{3}\sum_{j=1}^{7}\frac{\mathrm{CI}_{ij}\,\mathrm{ENS}_{ij}\,\mathrm{ENE}_i\,\mathrm{ECS}_i\,\mathrm{INC}\,\mathrm{POP}}{\mathrm{CO_2}}\\
&\quad\times\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnECS}_i}{dt}+\frac{d\mathrm{lnINC}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)\\
&\quad\times\sum_{i=T}\sum_{j=1}^{7}\frac{\mathrm{CI}_{ij}\,\mathrm{ENS}_{ij}\,\mathrm{ENE}_i\,\mathrm{VI}\,\mathrm{POP}}{\mathrm{CO_2}}\\
&\quad\times\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnVI}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)\\
&\quad\times\sum_{i=H}\sum_{j=1}^{7}\frac{\mathrm{ENS}_{ij}\,\mathrm{ENE}_i\,\mathrm{HI}\,\mathrm{POP}}{\mathrm{CO_2}}\\
&\quad\times\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnHI}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)
\end{aligned}
$$

Then, integrating over the time interval [0, T] yields

$$
\begin{aligned}
&\mathrm{In}\left(\frac{\mathrm{CO_2}_T}{\mathrm{CO_2}_0}\right)\\
&= \sum_{i=1}^{3}\sum_{j=1}^{7}\int_0^T w_{ij}\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnECS}_i}{dt}+\frac{d\mathrm{lnINC}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)dt\\
&\quad+\sum_{i=T}\sum_{j=1}^{7}\int_0^T w_{ij}\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnVI}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)dt\\
&\quad+\sum_{i=H}\sum_{j=1}^{7}\int_0^T w_{ij}\left(\frac{d\mathrm{InCI}_{ij}}{dt}+\frac{d\mathrm{InENS}_{ij}}{dt}+\frac{d\mathrm{lnENE}_i}{dt}+\frac{d\mathrm{lnHI}}{dt}+\frac{d\mathrm{lnPOP}}{dt}\right)dt
\end{aligned}
$$

Here, we employ the logarithmic mean for deriving the average share of each element of CO_2 emissions over the time interval [0, T] as the weight function ${w_{ij}}^*$, which is mathematically expressed as

$$
w_{ij}^* = \frac{L\left(\mathrm{CO_2}_{ij,0,}\,\mathrm{CO_2}_{ij,T}\right)}{L\left(\mathrm{CO_2}_{0,}\,\mathrm{CO_2}_T\right)}
$$