Part I
Asia Is a Key for a Sustainable Low-Carbon Society

Chapter 1
GHG Reduction Potential in Asia

Toshihiko Masui, Shuichi Ashina, Shinichiro Fujimori, and Mikiko Kainuma

Abstract Greenhouse gas (GHG) emissions from Asia accounted for approximately 38 % of global emissions in 2005. Considering the rapid economic growth expected in the coming decades, emissions from Asia in 2050 are projected to double the 2005 levels if efforts are not made toward achieving low-carbon societies (LCSs). The reduction of emissions in Asia is imperative for the transition by 2050 to an LCS worldwide that has halved GHG emissions. The LCS transition by Asian countries will not be an easy task. In order to accomplish this transition, it is vital that stakeholders including central and local governments, private sector enterprises, NGOs and NPOs, citizens, and the global community tackle it with a focused and common vision of the society they wish to achieve, while cooperating with one another and being aware of the roles they need to play. In addition, careful attentions should be placed on the diversity of the Asian countries when it comes to the implementation of countermeasures. Depending on the country or region in Asia, the level of development, amount and type of resources, climate conditions, culture, and other factors differ, and the actions that are effective may vary accordingly.

In order to analyze the feasibility, in this study two future scenarios, namely, advanced society scenario and conventional society scenario, are developed. In addition, "Ten Actions toward Low Carbon Asia," a guideline to plan and implement the strategies for an LCS in Asia, was developed. The ten actions are the following:

Action 1: Hierarchically connected compact cities
Action 2: Mainstreaming rail and water in interregional transport
Action 3: Smart ways to use materials that realize the full potential of resources
Action 4: Energy-saving spaces utilizing sunlight and wind
Action 5: Local production and local consumption of biomass
Action 6: Low-carbon energy system using local resources
Action 7: Low-emission agricultural technologies

T. Masui (✉) • S. Ashina • S. Fujimori
National Institute for Environmental Studies, Ibaraki, Japan
e-mail: masui@nies.go.jp

M. Kainuma
National Institute for Environmental Studies, Ibaraki, Japan

Institute for Global Environmental Strategies, Kanagawa, Japan

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Action 8: Sustainable forestry management
Action 9: Technology and finance to facilitate achievement of LCS
Action 10: Transparent and fair governance that supports low-carbon Asia

The contributions of the ten actions have been quantified by a global computable general equilibrium model. The model outputs showed that GHG emissions in Asia can be reduced by 20 gigatons of CO_2 equivalent ($GtCO_2$), i.e., 68 % of the emissions in the reference scenario, in 2050, if all the actions are applied appropriately.

In practice, on the other hand, it should be bear in mind that we need the smart strategies to meet the LCS pathways in each country depending on each development stages. For that purpose, knowledge sharing becomes important. It should be noted that the actions presented in this report are not the only pathway to achieve an LCS. The important point is to use this report to encourage discussions among stakeholders and to develop specific actions for each country or region in Asia.

Keywords Asia • Greenhouse gas • Low-carbon society • Transportation sector • Building sector • Industry sector • Renewable energy • Scenario • Global computable general equilibrium model

Key Messages to Policy Makers

- GHG emissions in Asia must be reduced drastically to meet the 2 °C target, which represents that the global mean temperature should be below 2 °C compared with preindustrial level.
- This paper presents common ten actions to achieve the low-carbon society in Asian countries although their situations are quite different.
- By applying the ten actions, Asia can reduce 68 % of GHG emissions in 2050 compared with the reference scenario.
- In practice, knowledge sharing among the countries is essential to achieve leapfrog development.

1.1 Introduction

Greenhouse gas (GHG) emissions from Asia have increased continuously and accounted for approximately 38 % of global emissions in 2005 (Fig. 1.1). Considering the rapid economic growth expected in the coming decades, emissions from Asia in 2050 are projected to double the 2005 levels if efforts are not made toward achieving low-carbon societies (LCSs). The Fifth Assessment Report of IPCC Working Group III (IPCC 2014) mentioned that, in order to achieve the 2 °C target, which is to limit the increase in global mean surface temperature to less than 2° C, the GHG emissions in 2050 and 2100 will have to be reduced by 41–72 % and 78–118 %, respectively,

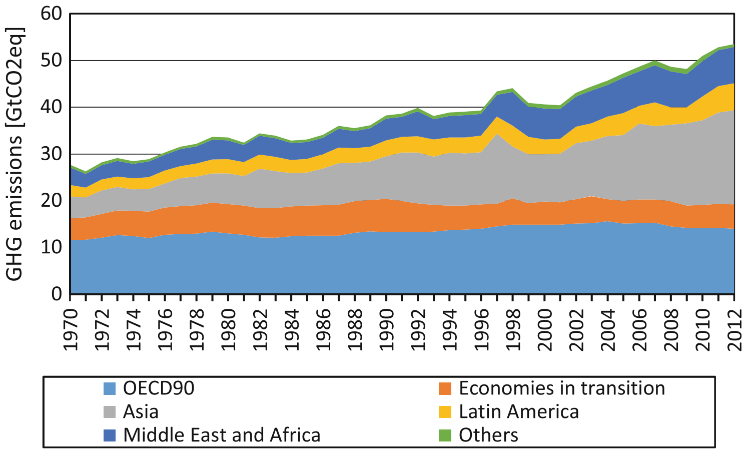

Fig. 1.1 Total GHG emissions by region between 1970 and 2012 (Notes: Data source is EDGAR v4.2 FT2012 (EDGAR 2014). Others include international aviation and shipping)

compared with the 2010 level. This means that the reduction of GHG emissions in Asia is imperative for the transition by 2050 to an LCS worldwide that has halved GHG emissions. As the energy consumption is expected to grow continuously with economic development, the reduction of CO_2 emissions from fossil fuel burning is an important goal. In addition, as the GHG emissions other than CO_2 emissions from fossil fuel burning account for approximately 40 % of the Asian GHG emissions, it is equally important to reduce them by actions like stopping deforestation, increasing CO_2 absorption from forestry, and decreasing such emissions from farmland and livestock. Furthermore, taking measures toward the realization of an LCS may also lead to the resolution of other key developmental challenges such as improving energy access, reducing local pollution, and eradicating poverty.

The LCS transition by Asian countries will not be an easy task. In order to accomplish this transition, it is vital that stakeholders including central and local governments, private sector enterprises, NGOs and NPOs, citizens, and the global community tackle it with a focused and common vision of the society they wish to achieve, while cooperating with one another and being aware of the roles they need to play.

In addition, careful attentions should be placed on the diversity of the Asian countries when it comes to the implementation of countermeasures. Depending on the country or region in Asia, the level of development, amount and type of resources, climate conditions, culture, and other factors differ, and the actions that are effective may vary accordingly (Fig. 1.2). However, guidelines showing the common requirements for realizing an LCS in Asia are extremely useful when each country considers measures and strategies that are highly feasible and effective.

There are many future scenarios, and future society will be diverse and uncertain. Based on the previous studies, we summarize the future scenarios of this study into two types: one is advanced society scenario and another is conventional society scenario (Kawase and Matsuoka 2013). Advanced society scenario will accept the new social system, institution, technologies, etc., positively and proactively. On the

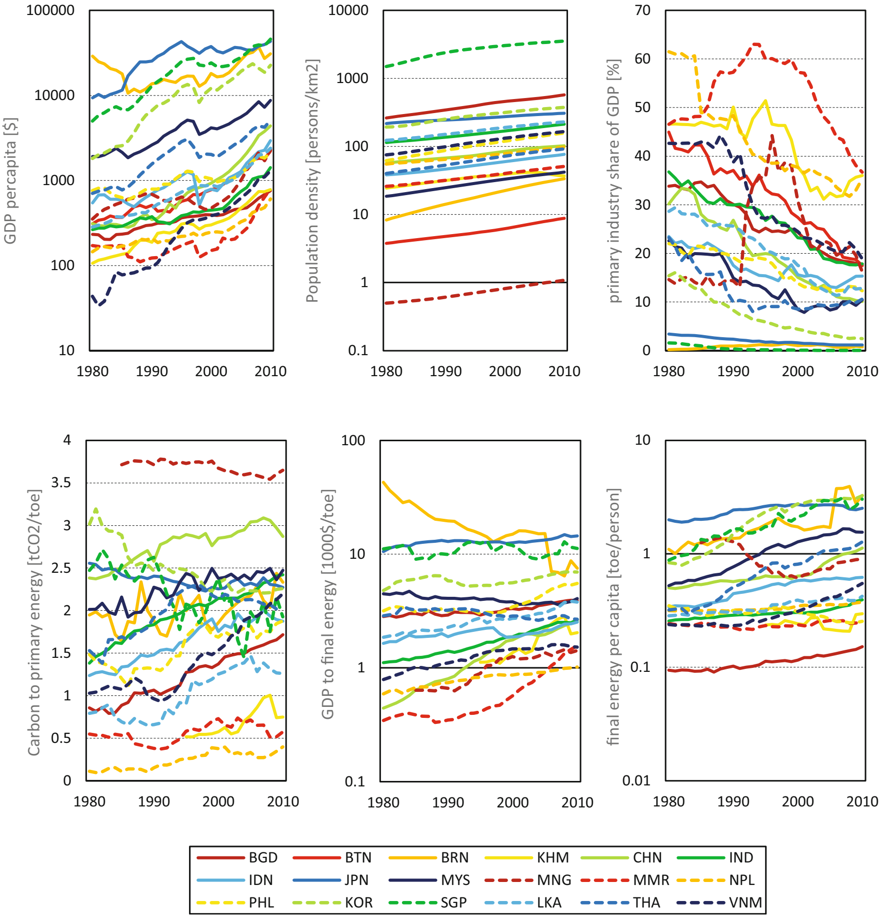

Fig. 1.2 Diversity and trends of Asian countries (Data source: UN Statistics Division 2015; IEA 2014a, b, c)

other hand, conventional society scenario will be discreet about the new social system, institution, technologies, etc., and worry about their transition cost. Table 1.1 shows the features of these two types of socioeconomic situations in Asia in 2050 for the quantitative analysis. The quantification in the following sections is based on Advanced Society Scenario.

1.2 Ten Actions to Achieve the Low-Carbon Society in Asia

In order to realize an LCS that satisfies the multifaceted needs and values of each Asian country, it is vital to gain the cooperation of a wide range of stakeholders, including policy makers, international aid agencies, private companies, local

Table 1.1 Assumptions of society in 2050

	Advanced society scenario (ADV)	Conventional society scenario (CNV)
Summary	Accepts the new social system, institution, technologies, etc., positively and proactively	Discreet about the new social system, institution, technologies, etc., and worries about their transition cost
Economy	Annual growth rate from 2005 to 2050, 3.27 %/year (global) and 4.16 %/year (Asia)	Annual growth rate from 2005 to 2050, 2.24 %/year (global) and 2.98 %/year (Asia)
Population	Total population in 2050, 9.3 billion persons in the world and 4.6 billion persons in Asia	
Education	Education system will be improved positively	Education system will be improved normally
	Education period, from 4–12 years in 2005 to 11–14 years in 2050	Education period, from 4–12 years in 2005 to 8–13 years in 2050
How to use time	Time for working and improving career will be longer	Time for staying with family or friends will be longer
Labor	Full employment in 2075	Fixed unemployment rate to 2009 level
Government	Efficiency will be improved immediately	Efficiency will be improved gradually
International cooperation	Reduction of trade barriers and FDI risks	Gradual improvement in collaborative relationships among Asian countries
Innovation	High	Medium
Transportation	Increase of demand due to high economic growth	Gradual increase of demand
Land use	More speedy and more efficient land use change	Moderate and careful land use change

communities, and NGOs, and share their long-term visions and strategies for an LCS. "Ten Actions toward Low Carbon Asia" as shown in Fig. 1.3 provides a guideline to plan and implement the strategies for an LCS in Asia (Low-Carbon Asia Research Project 2012, 2013). It takes into account the interrelationships between individual policies and the sequence in which they should be implemented. It also discusses the necessary actions to be taken by governments, private sectors, citizens, and international cooperation agencies on a priority basis.

In the following sections, each action is explained.

1.2.1 Hierarchically Connected Compact Cities

Economic growth has led to rapid motorization and urban sprawl in major cities in Asia, giving rise to various problems such as traffic congestion and air pollution. Nevertheless, most developing countries lack low-carbon, sustainable city planning. Many developing countries have prioritized road development in response to growing transport demand, resulting in a vicious circle in which even greater car use is induced. Since around 2000, major cities in Asia have begun to undertake urban railway development, but so far its level is not at all adequate. Developing

Fig. 1.3 Ten actions toward low carbon Asia

countries are also far behind developed countries in terms of vehicle technologies, as advanced technologies are not currently affordable.

Strategies for *low-carbon urban transport* are to AVOID unnecessary transport demand, to SHIFT transport modes to lower-carbon types, and to IMPROVE energy efficiency in transport. These can be realized with compact cities having well-connected hierarchical urban centers (AVOID strategy), a seamless and hierarchical transport system (SHIFT strategy), and low-carbon vehicles with efficient road traffic systems (IMPROVE strategy). Moreover, it is important to integrate urban transport systems with interregional transport systems in ways that reduce traffic congestion. Taking into account the CO_2 emission target of a city in a developing country, the national government is responsible for determining the appropriate types of urban structure and urban transport network consistent with the vision of interregional transport development. To support such development, international financing for green development needs to be greatly strengthened. Newly introduced international financial assistance should actively include low-carbon transport development. On the other hand, industries are responsible for developing electrification technologies for smaller vehicles to reduce congestion and CO_2 emissions. Citizens should thus be encouraged to explore a higher quality of life by using public transport and smaller vehicles, not following the conventional path of mobility growth to larger cars.

On the development pathway through 2050, according to urban agglomeration in cities along interregional rail corridors for passenger and freight transport, low-carbon urban transport systems can be developed. These transport systems will provide reliable services to support globalized economic activities by improving the efficiency of urban freight movement and increasing the speed of urban public transport. On the other hand, as resource constraints become more serious and Asian developing countries begin to become aged societies from 2030, systems adaptable to diverse transport requirements can be developed as urban infrastructure stock.

1.2.2 Mainstreaming Rail and Water in Interregional Transport

Demand for *international passenger and freight transport* has been growing in Asian developing countries compared with other regions in the world. Although international freight transport throughout Asia has low carbon emissions because it is dominated by marine transport, truck transport has been increasing for short- and medium-distance inland movement. Demand for international passenger transport in Asia, and the accompanying CO_2 emissions, has also been increasing in line with the development of the global economy and decreases in airfares due to the expansion of routes served by low-cost carriers.

Similar to the case of urban transport in Action 1, the AVOID strategy for reducing unnecessary transport demand, the SHIFT strategy for shifting to low CO_2-emitting transport modes, and the IMPROVE strategy for improving transport energy efficiency will be effective for establishing low-carbon interregional transport systems in Asia. Regarding the AVOID strategy, we propose rail-oriented development of industries on an interregional scale, in which high-speed freight railways form industrial corridors. For the SHIFT strategy, shifting away from road transport to intermodal transport based on the development of railways and waterways is necessary. In the case of the IMPROVE strategy, CO_2 emissions from vehicles, aircraft, and marine vessels can be reduced by electrification, alternative fuels, and lightweight body design. Within the continental region encompassing the area from China to the Greater Mekong Subregion (GMS), shifting from air to high-speed rail for passenger transport and from road to rail and waterways for freight transport will be highly effective. Additional reductions in CO_2 emissions can be achieved by industrial agglomeration along the high-speed freight railway corridors, which will be effective over medium and long distances in reducing the per unit time and cost. Through the implementation of these strategies, cities in coastal areas will become connected by low-carbon transport modes centered not only on maritime shipping but also on high-speed rail. A low-carbon transport system that combines high-speed rail, local rail, and technologically advanced large trailers can be introduced within the GMS region and the inland areas of China to connect with coastal areas, creating an intermodal transport system. Furthermore, by implementing an environmental impact tax, both the cost and environmental impact will be considered while siting industrial facilities and building supply chains. This will promote the formation of industry clusters along a low-carbon, interregional transport system that is centered on the mainstreaming of rail and water.

1.2.3 Smart Ways to Use Materials That Realize the Full Potential of Resources

Because of the increasing utilization of various *raw materials* such as steel and cement for the construction of social infrastructure, the penetration of durable goods, and the rising consumption of consumables in Asian nations, it is predicted that GHG emissions associated with these materials (from mining of natural resources and processing to final materials) will increase. The ratio of GHG emissions related to the production of such raw materials to gross GHG emissions is not negligible. The possibility also exists that resources used for mitigation technologies such as solar power, wind power, fuel cells, batteries, and the like might become insufficient as these technologies come to be extensively used.

The efficient utilization of these resources is therefore indispensable to achieve a meaningful reduction in GHG emissions. To attain this, it is necessary to employ innovative manufacturing that uses minimal resources, to use manufactured products as long as possible, and to reuse by-products and wastes repeatedly. Weight reduction of products, substitution of raw materials that emit excessive carbon with alternative materials, and longer life span of products should be promoted. Discarded products should be recycled using cleaner energy and better reused.

For governments, it is crucially important to design low-carbon cities and national land based on a medium- to long-term perspective to realize long-life infrastructure. Recycling and reuse systems should be established for various goods to enhance their reuse and recycling institutionally. Studies of efficient utilization of resources should also be supported. In industries, weight reduction, substitution of raw materials, and longer life span of products should be promoted to provide the same goods and services with less resource consumption and lower environmental emissions. Simultaneously, technologies related to the recycling and reuse of products and wastes should be developed and adopted.

Citizens are expected to play an important role in reducing GHG emissions related to resource use. In particular, lifestyles that are simple from a material viewpoint but create richness should be realized and practiced. For example, people could change their residence depending on each stage of life and use long-life products that allow recycling and reuse.

In addition to the above activities, international cooperation in the development and diffusion of technologies for efficient utilization of resources will reduce GHG emissions related to resource use in Asia. Furthermore, if environmental labeling systems for internationally traded products become accepted and upgraded, it will become possible for consumers to recognize and support the efforts made by producers.

1.2.4 Energy-Saving Spaces Utilizing Sunlight and Wind

As a number of Asian countries are located in tropical and subtropical regions, the demand of cooling service in the building sector has been rapidly increasing in line with their economic development and the pursue of comfort. In addition, in countries with template and subarctic zone, the demand of heating has also rapidly increasing in addition to the demand of cooling. Therefore, it is important to conduct the measures to respond to cooling and heating services in order to make low carbon in the *building sector*. In parallel, it is also necessary to address the measures to reduce the energy consumption from the appliances in the building sector as the number of appliances has been also rapidly diffused year by year in line with Asian countries' economic growth and the expansion of the economic activities.

In order to reduce the demand of cooling and heating services, it is imperative to design the buildings which can manage sunlight and humidity by making the ventilation. In line with the characteristics of each region's climate, it is also necessary to make device for insulation and make use of sunlight in order to provide sufficient cooling and heating services as well as enhance energy efficiency. Moreover, the development of *energy efficiency* building performance standard which suits to each climate zone will also contribute to the creation of high energy efficiency space.

In parallel, it is also necessary to provide financial support, such as subsidy and low interest rate loan in order to rapidly diffuse affordable high energy efficiency cooling and heating and other appliances by activating the competition to penetrate the market about the high energy efficiency appliance. The diffusion of high-efficiency appliance will assist reducing the energy demand and energy consumption in the building sector.

It is also imperative to provide social benefit in addition to the financial ones in order to promote the low carbonization in the building sector. Objective evaluation about the low-carbon activities by each business office and household, recognition of their best practices, and prize-giving to their great contribution will encourage the proactive activities toward the low carbonization.

It is essential to develop the mechanism to evaluate objectively about the effort by each stakeholder. Visualization of each stakeholder's effort by the third party's evaluation and prize-giving will be very important measures to reward their effort and encourage their continuous and proactive effort.

1.2.5 Local Production and Local Consumption of Biomass

Biomass energy can be used directly by end users or as an energy resource in production activities like power stations or other centralized energy supply facilities. It plays a vital role in low-carbon development in rural and urban areas of Asia.

Firewood and charcoal are primary energy resources used by households for cooking and hot water supply in many Asian countries. Their use causes serious health problems. Hence, improving living environments is an important associated issue for biomass use while achieving low-carbon development.

Using biomass energy as a major energy source in low-carbon Asia is ordained on establishing sustainable biomass production and utilization systems that avoid conflict with food production and forest conservation and promoting the consumption of these biomass resources locally. The installation of such energy supply systems using woody biomass, waste, and animal biomass in rural agricultural communities having plentiful biomass resources will enhance the supply of low-carbon energy, besides improving the standard of living.

For promoting the utilization of biomass in Asia, governments need to implement land use regulations and other policies that prevent conflict among "food, forest, and fuel."

Phasing out of fossil fuel subsidies is one policy which can immediately enhance competitiveness of biomass energy. In addition to supply-side policies, there are policies and measures that encourage citizens to follow sustainable land use and forest management practices that enhance biomass production and food production, minimize harvesting of forest biomass, and prompt agro-industry to make innovations of commercial biomass resources that do not compete with food production.

Since biomass production and use are dispersed, the global-scale research and development of biomass energy resources and conversion technologies, and the transfer of technology and the best practices, is very vital to develop the supply push ahead of the development of the global biomass market. In addition, the preferential support to biomass energy through carbon finance instruments, including the carbon credits, is key to promote demand-side pull from the energy market. In these contexts, the industry can play a central role in research and development, and the government's policies and programs could support the widespread adoption of such advanced biomass resources and technologies.

1.2.6 Low-Carbon Energy System Using Local Resources

Toward the realization of an LCS in Asia, the low carbonization in energy demand and supply has a vital role. Energy-saving activities and the application of *renewables* such as *solar photovoltaic (PV)* and *wind power* are keys to a reduction of GHGs. The use of renewable energies will also improve energy access, eliminate energy poverty, and establish sustainable local energy systems.

In a low-carbon Asia, it will also be essential to make fossil fuel-based energy supply systems more efficient and to facilitate coordination between fossil fuels and renewable energy, thereby improving energy security. Similarly, creation of a "smart" energy system that integrates the energy demand side will be vital. To establish these systems, governments have to develop a medium- to long-term energy policy that provides a clear direction domestically and globally on the key goals and related targets to be achieved. Achieving these goals and targets would, in the short to medium term, need institutional interventions and policy incentives that enable the introduction of renewables and energy-efficient appliances and facilities. In the long run, i.e., beyond 2030, the market pull in the wake of declining costs would deploy these technologies even without government incentives. In some countries, where the electricity access is limited by the short supply of infrastructure, the governments would have an important role to support the infrastructure supply.

The industrial sector in Asia experiences strong competition from outside the region as well as within the region. The technological innovations such as for improving grid control systems that can integrate and use diverse sources of electric power, as well as smart grids and demand responses, are important areas to enhance competitiveness of industries. Innovative industries have new market opportunities to innovate, develop, and supply solutions which can support the consumers showing preference for low-carbon or green energy sources such as solar PV systems or preferences for energy-efficient appliances or insulation technologies; the supply-side solution responds by integrating renewable energy and energy-efficient technologies to match the consumer preferences. International cooperation will also be essential. The establishment of an Asia grid network among Asian countries should be pursued using international financing mechanisms, and uniform standards should also be promoted in individual countries, creating an infrastructure for cross-border electric power interchanges. It will also be important to share best practices from the efforts in each country to encourage the use of renewable energies and to establish local weather information-gathering systems and share knowledge about the ways to use such systems.

1.2.7 Low-Emission Agricultural Technologies

The *agriculture sector* contributed 14.3 % of global anthropogenic GHG emissions in 2004, according to the Fourth Assessment Report of the IPCC (2007). To achieve the target of cutting global GHG emissions in half by 2050, mitigation options in the agriculture sector in Asia are expected to play an important role. Some mitigation measures contribute not only to GHG reductions but also to improvements in environmental conditions such as water quality and hygiene. In addition, as the cost of agricultural mitigation options is relatively low, they are attracting increasing public attention. To implement these measures, governments need to expand social infrastructure such as irrigation for water management in rice fields and to implement manure management plants for diffusion of low-emission agricultural technologies. They should also promote the dissemination of information on highly efficient fertilizer application. In particular, a gradual shift to the management of fertilization at the proper times and quantities is required in areas with excessive reliance on fertilizers. The agriculture sector should implement low-carbon water management such as midseason drainage by paddy farmers, collection of manure, and management of fertilizer and crop residues. Additionally, the methane gas emitted from manure should be actively utilized as an energy source. New technologies need to be positively adopted with the aim of achieving compatibility between productivity improvement and reduction of emissions.

If citizens select locally cultivated or raised products, local agriculture will be activated. Moreover, the selection of agricultural products produced by low-carbon farming methods will enhance their market value.

International activities are also important to promote the international joint development of low-emission agricultural technologies aimed at improving feed, livestock productivity, paddy field management, and so on. Additionally, international certification for low-carbon agricultural products should be introduced and its dissemination promoted.

CH_4 and N_2O are the main GHGs emitted by the agriculture sector. While energy-induced emissions, primarily CO_2, were a strong focus of attention in the 1990s, emissions other than CO_2 and emissions from nonenergy sectors, particularly CH_4 and N_2O, have begun to attract more attention since then have shown that the nonenergy sectors and non-CO_2 gases can potentially play an important role in future climate change mitigation, although there is greater uncertainty in estimating CO_2 emissions from land use and CH_4 and N_2O emissions than in estimating CO_2 emissions from fossil fuels.

1.2.8 Sustainable Forestry Management

Deforestation reduces forest carbon stocks, creates soil disturbances, and increases CO_2 emissions. It causes degradation of remaining forestland and lower wood productivity and inflicts severe damage on biomass growth. It is therefore important to reduce the impact of logging and improve the maintenance of *forested areas* so as to halt forest degradation, thereby reducing GHG emissions and enhancing the function of forests as a carbon sink.

Planting of trees on land that was not previously forestland is called afforestation, while planting of trees on land where a forest existed is referred to as reforestation. The Kyoto Protocol treats both afforestation and reforestation as methods of reducing emissions under the *Clean Development Mechanism.* Carbon is absorbed by trees through photosynthesis and stocked in forests and soils.

In Indonesia, peat fire and peat decomposition are major emission sources in the land use sector. Both fire management and peatland management are necessary to mitigate these emissions, in conjunction with the suppression of illegal logging, protection of ecosystems, and reduction of poverty.

To manage fires and peatland, the government is expected to play an important role by implementing land use zoning for forest protection, stopping illegal logging and unplanned land clearance, supporting the economic independence of local people by enhancing their level of education, and introducing licenses for tree planting and land clearance to encourage sustainable land use by landowners.

The private sector is expected to conduct logging and planting operations sustainably on properly licensed land, appropriately manage fires lit for land clearance, acquire forestry management skills for appropriate logging and forestation, autonomously maintain land after logging for forest regeneration, and abstain from illegal logging and consumption of illegally logged timber.

Citizens should be encouraged to understand the importance and multiple functions of forest ecosystems and to manage forests at the local level. They can contribute to reduced emissions by selecting products made of certificated wood as much as possible and actively participating in programs implemented by the government, NPOs, international society, etc. In the area of international cooperation, it is important to establish international systems to certificate sustainable management of biofuel and wood production and to regulate the importation of products that do not meet the criteria. Additionally, promotion of international cooperation for forestation and capacity development in timber-producing areas is required.

1.2.9 Technology and Finance for a Low-Carbon Society

To achieve LCSs in Asia as rapidly as possible, existing *low-carbon technologies* must be deployed and commercialized, and innovative new technologies must be developed. For these things to happen, national governments need to establish an environment for the industrial sector to invest with confidence in innovative research. They also need to create frameworks in Asia at the regional level in which each country's private sector can develop efficient technologies that will play a key role in the development of low-carbon products and deliver these products to the general public. At the present time, however, many institutional, economic, financial, and technological barriers exist that are preventing technology transfer and technology diffusion. Many studies in Asia have found that these barriers differ significantly by country and technology.

In China, India, and Thailand, for example, technologies such as wind power and bioenergy electricity production that are ready for diffusion and technology transfer for commercial use may encounter such barriers as high patent acquisition costs or a lack of local expertise with regard to imported technologies and lack of know-how and skills for their operation and maintenance. For technologies such as LED lighting or photovoltaics that are ready for diffusion and technology transfer for business or consumer use, the barriers may be the small size of the market and an exceedingly small amount of investment from overseas. Because these barriers differ depending on the stage of technological development, level of diffusion, or stage of technology transfer, governments need to consider what funding, technology policies, and support programs might be required, depending on the stage of the technology life cycle. They also need to implement this in collaboration with the private sector and the relevant international bodies.

The pool of private sector funding available holds the key to the early transfer and spread of low-carbon technologies. In the past, under the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, the Global Environment Facility acted as an interim funding institution, providing funding to developing countries. After three funds were set up (the Special Climate Change Fund, the Least Developed Countries Fund, and the Adaptation Fund), however, many issues arose including a shortage of funds and the need to determine priorities for the limited funds available. To overcome this situation, the Green Climate Fund was established in 2010 under the Copenhagen Accord of 2009, and it was stipulated that developed countries were to supply 100 billion US dollars every year until 2020. However, this amount represents a huge jump in public funding, and the search is still on to find ways to secure the funds. Exacerbating this situation is the disappointing progress of multilateral negotiations under the UNFCCC. Because urgency is required in the Asian region – as it is undergoing rapid economic development – it is necessary to consider ways to procure funds especially in this region, without waiting for further progress in multilateral negotiations. Past levels of aid from developed to developing countries cannot meet the level of funding required for the spread of technologies and products. In addition to the funding provided by developed countries under the UNFCCC and official development assistance, there is a need to find ways to mobilize diverse sources of public and private funding in the Asian region.

1.2.10 Transparent and Fair Governance That Supports Low-Carbon Asia

For Asian countries to become LCSs and enjoy the related benefits, all actors – governments, industry, citizens, and international society – need to share a common vision and strategy for an LCS. It is essential to plan, implement, and evaluate the options, with coordination of each of the respective roles.

In the past, in order to achieve the GHG emission reduction targets allocated under the Kyoto Protocol, a variety of related policy frameworks were established, and there was much discussion about the roles of national governments in implementation. To truly create LCSs, however, we cannot avoid the need for reallocation of resources and burdens in the domestic context. However, political interests can become a major factor in some cases, and it becomes difficult for national governments to plan and implement effective policies. Furthermore, due to rapid economic development, GHG emissions from developing countries – which are not under legally binding obligations to reduce emissions – are rising significantly. It will not be possible to limit the global temperature increase to 2 °C if discussions and efforts continue at the current pace for achieving emission reduction targets that were adopted based on the concept of equity when the UNFCCC entered into effect. The answer to the question of what is a fair reduction varies significantly depending on a country's perspective of what is "fair." Thus, for "*low-carbon governance*" that will achieve large, long-term reductions in GHG emissions in order to achieve the 2 °C target, national commitments are important, but it is also important that other nongovernmental stakeholders make voluntary commitments, depending on their ability to do so. Also, it will be important to create institutional designs that will allow mainstreaming of low-carbon policy, in an integrated way, of the frameworks that have so far been built on a sector-by-sector basis. And, based on them, it will be important to create efficient administrative management frameworks.

Notably, many Asian countries have formulated action plans to become LCSs, but in many cases the plans are not being implemented, or, even if they are being implemented, the effects are limited. In some cases, government fraud or corruption due to inadequate legislation or governance results in a failure to effectively utilize physical, economic, and human resources. Also, due to inadequacies in governments' management philosophy or concepts, it is not uncommon to see redundancy of policies and measures by different government ministries and agencies or inadequate sharing of information.

In this context, as a national-level initiative to establish LCSs in Asia, it is necessary to build the foundations of transparent and accountable government and to institute corruption prevention measures in the public sector, including central and local (municipal) governments. Meanwhile, the international community is expected to provide support to accelerate those efforts at the national level. For example, the World Bank and other institutions have developed frameworks for country-specific evaluations of public sector policies and institutions, and attempts are being made to reflect these efforts in their international assistance. Thus, strengthening the role of the international community in encouraging improvements in public sector management in Asian countries could be a major step forward to implement policies and measures proposed under Actions 1 through 9 of this document.

Also, as described below, Asian countries are characterized by the diversity of their political systems, and they need to plan and implement policies not only for sustainable development but also other development objectives, such as reducing health problems and poverty. In many cases, the differences between countries are mainly in scale, but they have much in common. Thus, there is a need for intergovernmental policy coordination in the planning and implementation of policies that have some compatibility between development objectives and GHG emission reductions.

Regarding the public-private sector relationship, in the past there has been excessive protection of government-related and/or certain private companies. However, it is important to establish healthy public-private partnerships by establishing objective standardization and certifications.

1.3 GHG Reduction by Introducing "Ten Actions"

The contributions of the ten actions have been quantified by a global computable general equilibrium model. The model used here divides the world into 17 regions as shown in Table 1.2 and contains the categories of governments, households, and producers. The production is classified into 32 goods. The model deals with power generation technologies in detail. This report depicts the advanced society scenario developed by the Low-Carbon Asia Research Project. About the more detailed model structure, please see Fujimori et al. (2012, 2013). Figures 1.4, 1.5, and 1.6 show the trajectories up to 2050 in population, GDP, and primary energy supply by region in the reference scenario, respectively. First, the GHG emissions in the reference case of the advanced society scenario in Table 1.1 are estimated. Then, the LCS scenarios with the ten actions are quantified, targeting a halving of global GHG emissions by 2050. Subsequently, the emission reductions and the contribution of each action in 2050 are estimated.

Table 1.2 Regional classification in this analysis

Japan (JPN)	EU25	Brazil
China (CHN)	Rest of Europe	Rest of Latin America
India (IND)	CIS	Middle East
South East Asia + Rest of East Asia (XSE)	Turkey	North Africa
Rest of Asia (XSA)	Canada	Rest of Africa
Oceania	USA	

Note: The five gray cells are regarded as Asia

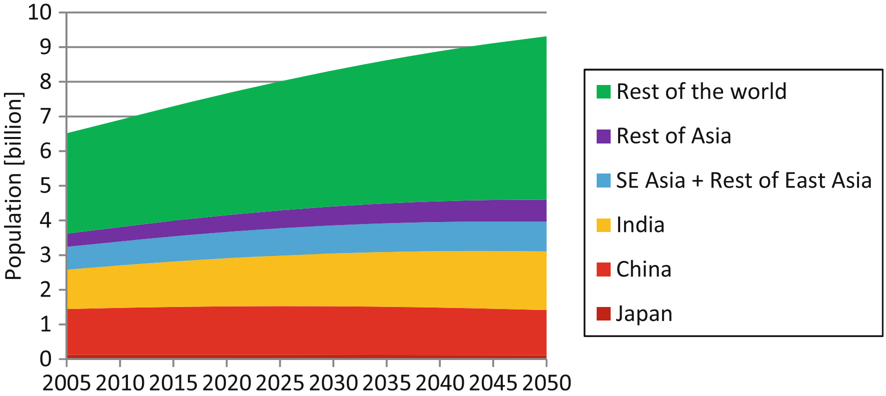

Fig. 1.4 Regional population trends by 2050 in reference scenario (unit, million)

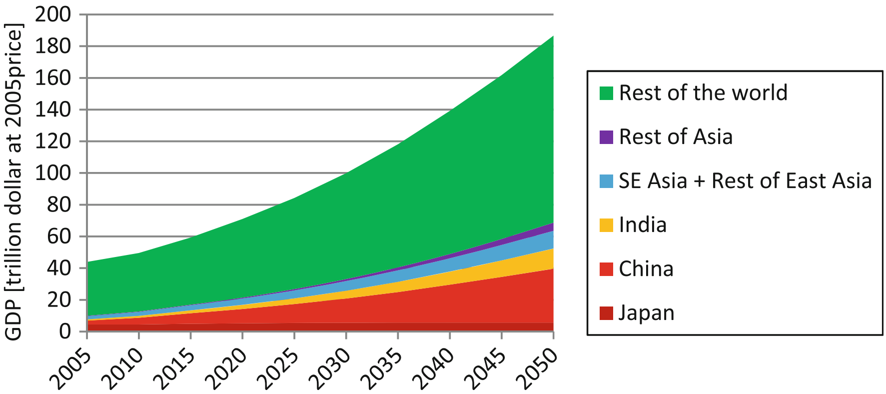

Fig. 1.5 GDP trends by 2050 in reference scenario (unit, trillion $ at 2005 price)

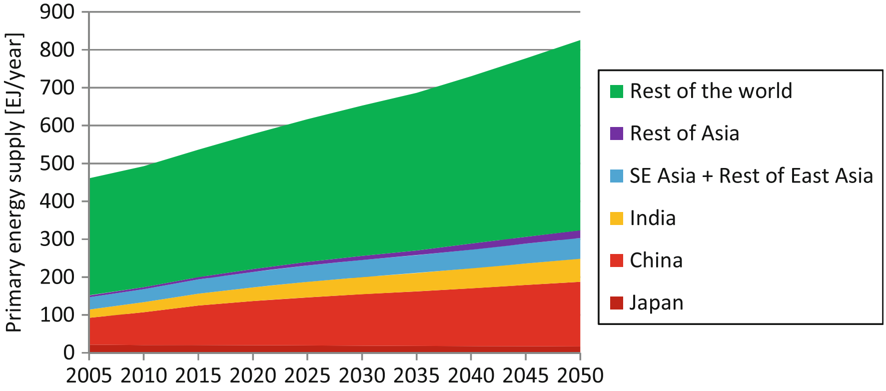

Fig. 1.6 Primary energy supply by 2050 in reference scenario (unit, EJ/year)

Figure 1.7 shows the future GHG emissions in Asia and the world in reference scenario and LCS scenario. As for the Asia, the quantities of GHG emission reduction by actions are also represented.

1.3.1 *Feasibility of Reducing GHG Emissions by 68 %*

If all the actions are applied appropriately, GHG emissions in Asia can be reduced by 20 gigatons of CO_2 equivalent ($GtCO_2$), i.e., 68 % of the emissions in the reference scenario, in 2050. These include all the ten actions covered in this report, and some other actions for CH_4 and N_2O emission reduction in non-agriculture sectors. Figures 1.8 and 1.9 show the primary energy supply by energy type and electricity generation by technology in Asia, respectively. From these figures, the energy saving becomes important through 2050. Moreover, introduction of

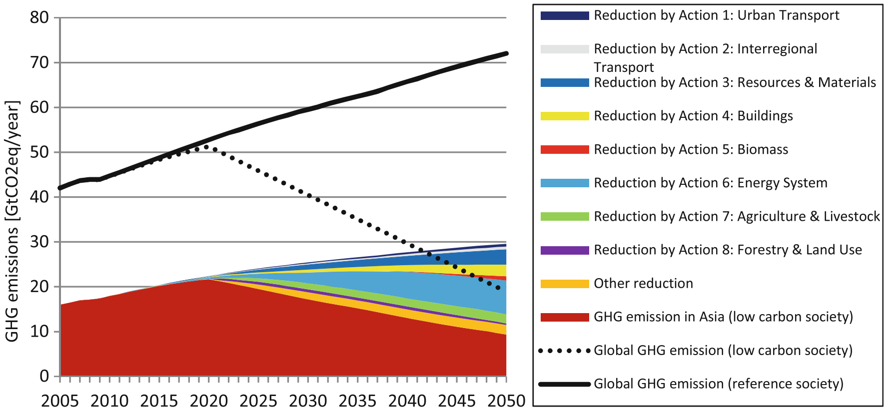

Fig. 1.7 GHG emissions in low-carbon Asia

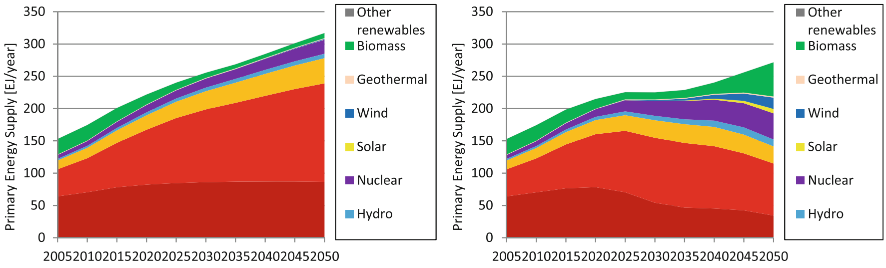

Fig. 1.8 Primary energy supply in Asia by energy type: reference scenario (*left*) and LCS scenario (*right*)

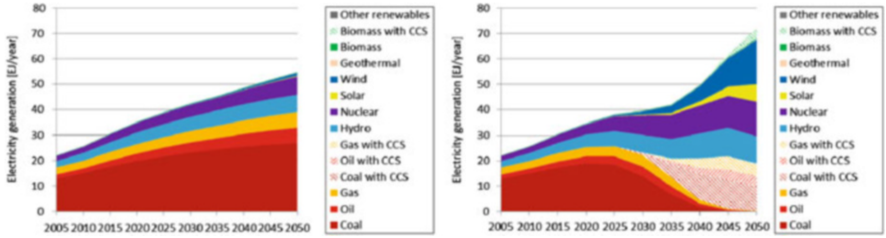

Fig. 1.9 Electricity generation in Asia by technology: reference scenario (*left*) and LCS scenario (*right*)

non-carbon energies, which include renewable energies and fossil fuels with carbon capture and storage (CCS) technology, becomes important after 2030. The share of fossil fuels in LCS scenario becomes smaller than that in reference scenario, and in the fossil fuel thermal power sectors install the CCS technology.

Actions 1 and 2, which focus on transportation, account for a combined share of 6.1 % of the total reduction in Asia. The share of Action 3, which aims to lower carbon emissions in the usage of materials, is 17 %, while the share of Action 4, which encourages energy saving in buildings, is 13 %. The share of Action 5, which utilizes biomass energy, is 4.7 %, and the share of Action 6, which is related to other energy supply systems, is 37 %. The shares of Actions 7 and 8, dealing with agriculture and forestry, are, respectively, 10 % and 1.6 %. The remaining 11 % of the reduction is accounted for by measures that are not listed in this report. The results of the actions will vary according to each country and region. For example, Actions 3, 4, and 6 will be effective for most countries and regions, whereas the contribution of Action 7 will be the largest in XSA&XOC (South Asia excluding India and small island states in Oceania) and the second largest in India.

1.4 Conclusion

As is discussed in the previous section, GHG emissions in Asia must be reduced drastically to meet the 2 °C target. In order to analyze the feasibility of such deep reduction, two scenarios are developed and analyzed in detail, namely, reference scenario and LCS scenario, and ten actions to meet the low-carbon Asia are identified. The analysis shows that it is possible to reduce the GHG emissions drastically in Asia by appropriately applying such actions. The reduction can reach 68 % from reference case. In other words, leapfrog development can be achievable in Asia.

In practice, on the other hand, it should be bear in mind that we need the smart strategies to meet the LCS pathways in each country depending on each development stage. For that purpose, knowledge sharing becomes important. It should be noted that the actions presented in this report are not the only pathway to achieve an LCS. The important point is to use this report to encourage discussions among stakeholders and to develop specific actions for each country or region in Asia.

Acknowledgment This chapter is a summary of final results of Low-Carbon Asia Research Project supported by the Environment Research and Technology Development Fund by the Ministry of the Environment, Japan (S-6-1). The authors express their thanks to all the members who contributed to this project.

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Chapter 2
Transition to a Low-Carbon Future in China Towards 2 °C Global Target

Jiang Kejun, Chenmin He, and Jia Liu

Abstract The purpose of low-carbon development in China is for both national sustainable development and global climate change action. For the global climate change target 'to hold the increase in global average temperature below 2 °C above preindustrial levels', China needs to peak in CO2 emissions by 2025 *at the latest* and then secure deep cuts in CO2 emissions. Previous studies on emission scenarios show that it is possible for China to peak in CO2 emissions by 2030 if strong policies are adopted, albeit at relatively high cost. In other words, peaking in CO2 emissions before 2025 represents a huge challenge for China. A modelling study conducted by IPAC on the 2-degree target stated that it is also still possible for China to peak in CO2 emissions before 2025 as long as several preconditions are satisfied, including optimised economic development, further energy efficiency improvements, enhanced renewable energy and nuclear development and CCS.

Energy-intensive industries consume more than 50 % of energy in China and account for more than 70 % of newly increased power output. Scenario analysis shows that many energy-intensive product outputs will reach a peak before 2020, with a much slower growth rate compared with that in the 11th Five-Year Plan, and therefore will significantly change the pathway for energy demand and CO2 emissions.

Energy efficiency should be further promoted. In the 11th Five-Year Plan, energy efficiency was improved significantly, and by reviewing what happened in this Plan compared to energy conservation efforts over the last several decades, as well as effort in other countries, it can be seen that China is now making unprecedented efforts in energy conservation. The target is to make China's energy efficiency in major sectors one of the best by 2030.

China is a now a leading country in new energy and renewable energy. Based on planning taking place in China, by 2020, renewable energy will provide 15 % of the total primary energy, which includes renewable energy excluded from the national energy statistics.

J. Kejun (✉) • C. He • J. Liu
Energy Research Institute, Beijing, China
e-mail: kjiang@eri.org.cn

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Another key factor is the increase in natural gas use in China. In the enhanced low-carbon scenario, natural gas use will be 350 BCM by 2030 and 450 BCM by 2050; and in the 2-degree scenario, it will be around 480 BCM by 2030 and 590 BCM by 2050. Together with renewable energy, this leaves coal use in China by 2050 at below 1 billion tonnes.

For CO2 emissions, carbon capture and storage could further contribute to CO2 emission reduction. China has to use CCS if large amounts of coal are used for the next several decades, but even with the enhanced low-carbon scenario, coal use will be around 1.8 billion tonnes by 2050.

Technological progress is a key assumption for a low-carbon future for China. The cost learning curve for wind and solar and many other technologies is much stronger than the model used. Such progress greatly reduces costs in wind power and solar power within 2 years.

Keywords Emission scenario • CO2 mitigation • Modelling • Energy transition • Emission target • China

Key Message to Policymakers

- In order to achieve ‘2-degree’ global target, China’s CO2 emissions have to be at peak before 2025.
- China can peak CO2 before 2025 and reduce emission 70 % by 2050 compared with that in 2020.
- Setting a cap for CO2 emissions in China is an effective way to limit CO2 emission increases.

2.1 Background

In December, 2009, the Copenhagen Accord declared that deep cuts in global emissions are required ‘so as to hold the increase in global temperature below 2 degrees Celsius’. At the climate conference in Cancun 1 year later, parties decided ‘to hold the increase in global average temperature below 2 °C above preindustrial levels’ and made a decision for ‘strengthening the long-term global goal on the basis of best available scientific knowledge including in relation to a global average temperature rise of 1.5 °C’. The Copenhagen Accord called for an assessment that would consider strengthening the long-term goal. Further, the IPCC AR5 called on research communities to work on assessments by modelling on the emission pathway and feasibilities for the global target.

Recently, several global emission scenario studies present emission scenarios focusing on the 2-degree target, which requires global emissions to peak by 2020 at the latest (IPCC 2014). However, the commitment in the Copenhagen Accord does not agree with the global 2-degree target scenarios, which implies that further efforts are needed by each country. It is thus essential to perform more analysis at the country level to assess the potential for CO2 emission mitigation to follow the global 2-degree target pathway. This paper presents the key factors China needs to consider in order for it to follow the global target, based on modelling results from the IPAC modelling team in Energy Research Institute (ERI).

GHG emissions from energy use in China surpassed those of the United States in around 2006 and accounted for around 29 % of global emission in 2013 (Olivier et al. 2013). And due to rapid economic development, CO2 emissions are expected to increase significantly in the coming decades (IEA 2011; Kejun et al. 2009). This presents China with a huge challenge to peak in CO2 emission before 2025 and start deep cuts after 2030. Much more effort is thus required, not only in China, but by the reset of the world.

2.2 Emission Scenarios

2.2.1 Methodology Framework

In this study we used the linked Integrated Policy Assessment Model of China (IPAC) for the quantitative analysis, which covers both global emission scenario analysis and China's national emission scenario analysis. IPAC is an integrated model developed by ERI and analyses effects of global, national and regional energy and environment policies. ERI itself has conducted long-term research in developing and utilising energy models since 1992 (Kejun et al. 2009).

In order to analyse global emission scenarios and China's emission scenario, three models are used, one being global and the other two national: the IPAC-Emission global model, the IPAC-CGE model and the IPAC-AIM/technology model. The three models are linked as shown in Fig. 2.1. The modules in IPAC are currently soft linked, which means the output from one module is used as the input for another.

The IPAC-Emission model is a global model within the IPAC family and presently covers nine regions, to be extended to 22. Because this model focuses on energy and land use activities, in order to simulate other gases emissions, the model was revised to cover the analysis for HFC, PHC, SF6, CH4 and N2O.

The IPAC-Emission global model is an extended version of the AIM-Linkage model used in IPCC Special Report on Emission Scenarios (SRES) (Kejun et al. 2000), which links social and economic development, energy activities and land use activities and offers a full range of emission analyses. The IPAC-Emission global model comprises four main parts: (1) society, economy and energy activities module, which mainly analyses demand and supply under conditions of social and economic development and determines energy prices; (2) energy technology module, which analyses the short- and mid-term energy utilisation technologies under different conditions and determines the energy demand under different technology

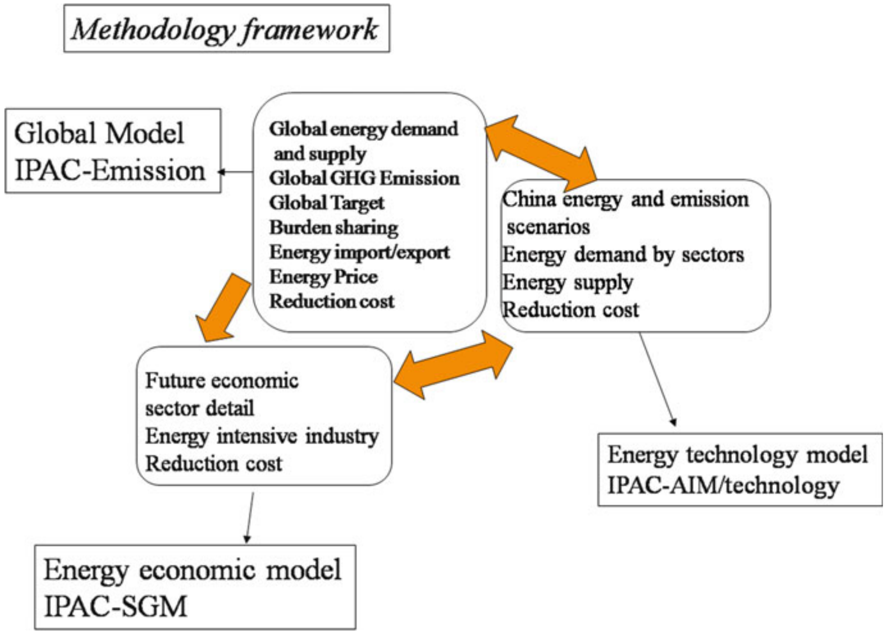

Fig. 2.1 Links among models in the research

compositions. The energy demand in this module modifies the short- and mid-term energy demand in module (1) so that the energy analysis in the macroeconomic model can better reflect short- and mid-term energy activities; (3) land use module, which analyses emissions from land use processes; and (4) industrial process emission module, which mainly analyses emissions from industrial production.

IPAC-AIM/technology is the main component of the IPAC model (Kejun et al. 1998), and it performs analyses based on the cost-minimization principle, i.e. technologies with the least costs will be selected to provide the energy service. The current version of IPAC-AIM/technology model includes 42 sectors and their products and more than 600 technologies, including existing and potential technologies.

IPAC-SGM is a computable general equilibrium model (CGE model) for China. It is mainly responsible for analysing the economic impacts of different energy and environmental policies and can analyse mid- and long-term energy and environment scenarios. IPAC-SGM divides the overall economic system into household, government, agriculture, energy and other production sectors, 42 in total.

The key focus of this study is how China can support the global 2-degree target based on its emission pathway, as well as related issues. In order to analyse the feasibility of the 2-degree target for China's emission pathway and related options, we start from the global modelling analysis performed on the target to learn how China's current emissions are affected by the 2-degree emission scenario. Then the options for the 2-degree target for China are analysed via the national model, based on the previous emission scenario analysis for China.

In the IPAC scenario setting for China, input is also needed from other relevant studies, such as GDP, population and sector outputs (Shantong 2011; Xueyi and Xiangxu 2007). The IPAC modelling team also performed studies on these parameters by using IPAC-SGM and the population model. Economic activity is becoming one of the key research topics within IPAC modelling studies due to the large uncertainty surrounding economic development and its heavy impact on energy demand. Sector development trends are crucial for energy and emission scenarios in the modelling studies, as around 50 % of total final energy use in China is accounted for by energy-intensive sectors such as ferrous and non-ferrous metal manufacture, building material manufacture and the chemical industry (China Energy Statistical Yearbook 2013 2013). In the meantime, demand for energy-intensive products was simulated by input-output analysis with a focus on downstream sector development analysis. Table 2.1 gives a scenario for energy-intensive product output in China used in the emission scenarios.

The national analysis on economic development could much more reflect national experts' viewpoints, which normally has quite big difference with the global projection on China's GDP growth. This could be seen in comparison between global modelling excises and China's national model analysis, such as IEA's World Energy Outlook (WEO) and IPAC model (IEA 2011; Kejun et al. 2009). And the sector study for output analysis could present much more sight inside economy structure change, to think about the contribution for lower energy demand and emission from economic structure change.

2.2.2 Global Emission Scenarios and Regional Allocation

The global emission scenario from IPAC mainly comes from the IPAC-Emission global model, with recent studies focusing on global mitigation scenarios. Here, a 2-degree scenario was developed based on the IPAC 450 ppm emission scenario model, as shown in Fig. 2.2. A simplified climate model, MAGICC, was used to set up the CO2 concentration at 450 ppm by year 2100 (Wigley and Raper 2001).

Regional allocation of emissions from the global emission scenario was given by using the 'burden-sharing' method. There are several ways to share the burden of emission reduction, and the subject itself has attracted much political discussion as regards whether to base it on emission per capita convergence, accumulated emission per capita convergence or something else. Sidestepping the politics, the method we used is the widely used model based on the per capita emission convergence method. With the global emission scenario from the global model, regional emission allocation was performed using CO2 emission per capita convergence criteria.

Table 2.1 Production of selected energy-intensive products

	Unit	2005	2020	2030	2040	2050
Iron and steel	10^8 tonnes	3.55	6.7	5.7	4.4	3.6
Cement	10^8 tonnes	10.6	17	16	12	9
Glass	10^8 weight cases	3.99	6.5	6.9	6.7	5.8
Copper	10^4 tonnes	260	700	700	650	460
Aluminum	10^4 tonnes	851	1600	1600	1500	1200
Lead and zinc	10^4 tonnes	510	720	700	650	550
Sodium carbonate	10^4 tonnes	1467	2300	2450	2350	2200
Caustic soda	10^4 tonnes	1264	2400	2500	2500	2400
Paper and paperboard	10^4 tonnes	6205	11,000	11,500	12,000	12,000
Chemical fertilizer	10^4 tonnes	5220	6100	6100	6100	6100
Ethylene	10^4 tonnes	756	3400	3600	3600	3300
Ammonia	10^4 tonnes	4630	5000	5000	5000	4500
Calcium carbide	10^4 tonnes	850	1000	800	700	400

Source: Author's research result

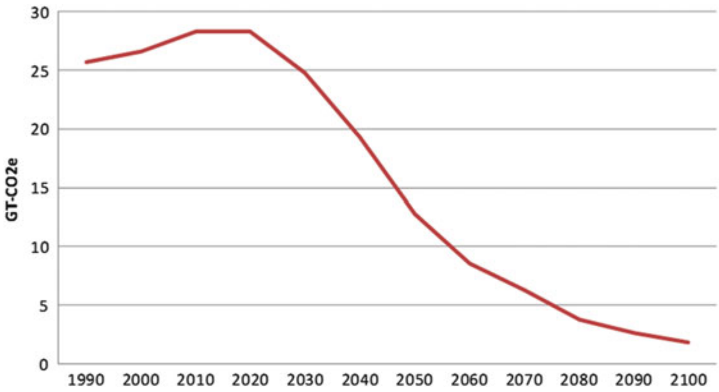

Fig. 2.2 Global CO2 emissions at 450 ppm by 2100 (Source: Author's research result)

When burden sharing using emission per capita is analysed, certain assumptions are made:

- Year to reach emission per capita convergence: here, we use 2070.
- Annex 1 countries will start reduction based on the Kyoto commitment and then proceed to deep reductions. Non-Annex 1 countries will start to depart from baseline emissions from 2010.
- CO_2 emission per capita in some developing countries may exceed developed countries.
- Population in IPAC model comes from IIASA analysis. Figure 2.3 gives the CO_2 emissions by major regions and countries.

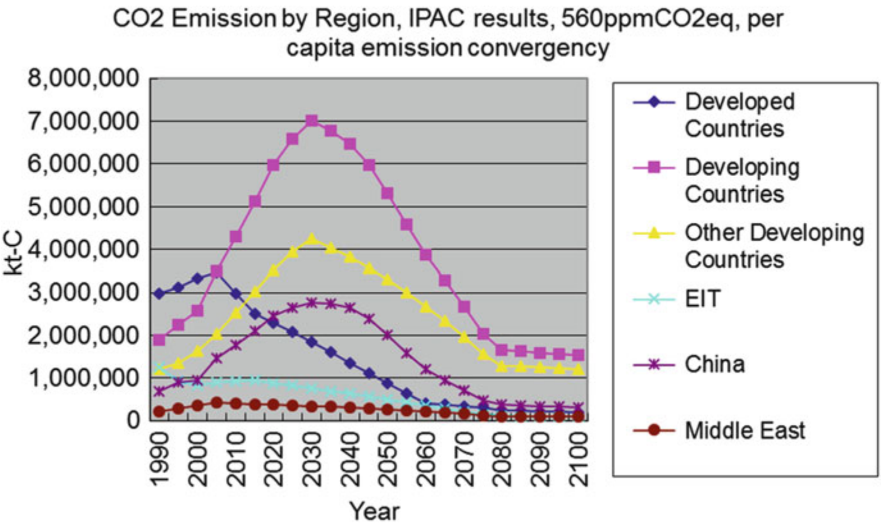

Fig. 2.3 Emissions in regions based on per capita emission convergence burden sharing (Source: Author's research result)

In order to allow more leeway for the emissions of developing countries in the future, developed countries need to make deep reductions as soon as possible. In the analysis, we also assumed other developing countries will do their part in CO2 mitigation, based on country developments and international collaboration.

The technological feasibility was also considered, which was based on the global emission scenario study from IPAC model. Figure 2.3 presents a picture for emission reduction in 2020 towards the 2-degree target.

2.2.3 China's Emission Scenarios

The IPAC team developed and published emission scenarios for China (Kejun et al. 2008, 2009), which comprise the three scenarios: baseline, low carbon and enhanced low carbon. The enhanced low-carbon (ELC) scenario involves China peaking in CO2 emissions by 2030 and then starting to decrease after that.

From Fig. 2.3, we can see China's CO2 emissions peaking at around 2025 at 8.56 billion tonnes, in order to reach the global 2-degree target. This is tougher than the enhanced low-carbon scenario from IPAC. With the assumption on GDP, the carbon intensity from 2005 to 2020 will be in the range of 49–59 % for these scenarios, which is much higher than the government target announced.

The government target announced based on a 40–45 % carbon intensity reduction between 2005 and 2020 is realised via domestic efforts. On the one hand, it is possible for China to do better if existing policies on energy efficiency, renewable energy and nuclear energy continue over the next two Five-Year Plans but with more emphasis placed on low-carbon development and low-carbon transport and

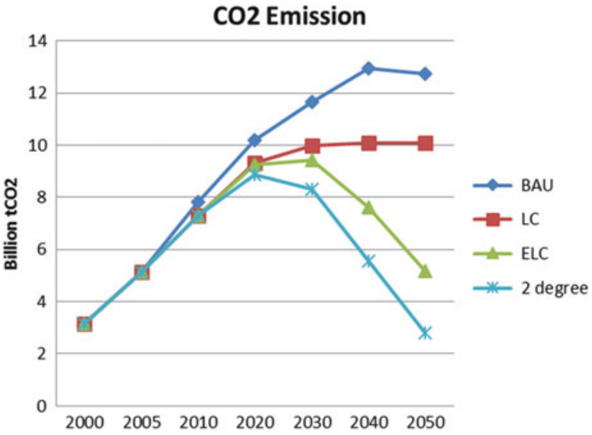

Fig. 2.4 CO2 emission scenario in China (Source: Author's research result)

lifestyle; on the other hand, it is also possible to go further with international collaboration via technology collaboration, international carbon financing, carbon market and so on. Basically, the possibility for China to do better is high.

In order to analyse the feasibility for China, one more scenario—the 2-degree scenario for China—was given using the same model. Under this modelling analysis, we can see economic activities, energy activities, technology progress and lifestyle change in much more detail. The 2-degree scenario was developed based on the enhanced low-carbon scenario by pursuing further action in order to assess the feasibility.

Figure 2.4 presents the results for the new scenario family.

2.3 Key Factors in the Low-Emission Pathway

In the modelling analysis, key areas for CO2 emissions include economic development optimisation, energy efficiency improvements, renewable energy and nuclear development, carbon capture and storage and change of lifestyle and consumption. Efforts in the IPAC *modelling* study were based on the possibility of key assumptions by taking a broad look at driving forces, technology, the environment, social development and so on. In the enhanced low-carbon scenario, in order to reach the peak by 2030 and then start to decrease in CO2 emissions, several key challenges have to be overcome:

Change in economic structure. There was much discussion during the scenario building with the invited economics experts, as well as reviews of related studies. The GDP growth used here is the most commonly used result obtained from economic research teams, especially concerning pre-2030. Economic structural change in the three industrial sectors also presents a middle line, based on the literature reviewed. However, there is little research quantitatively detailing structural change within secondary industry. Here, based on the available research, we

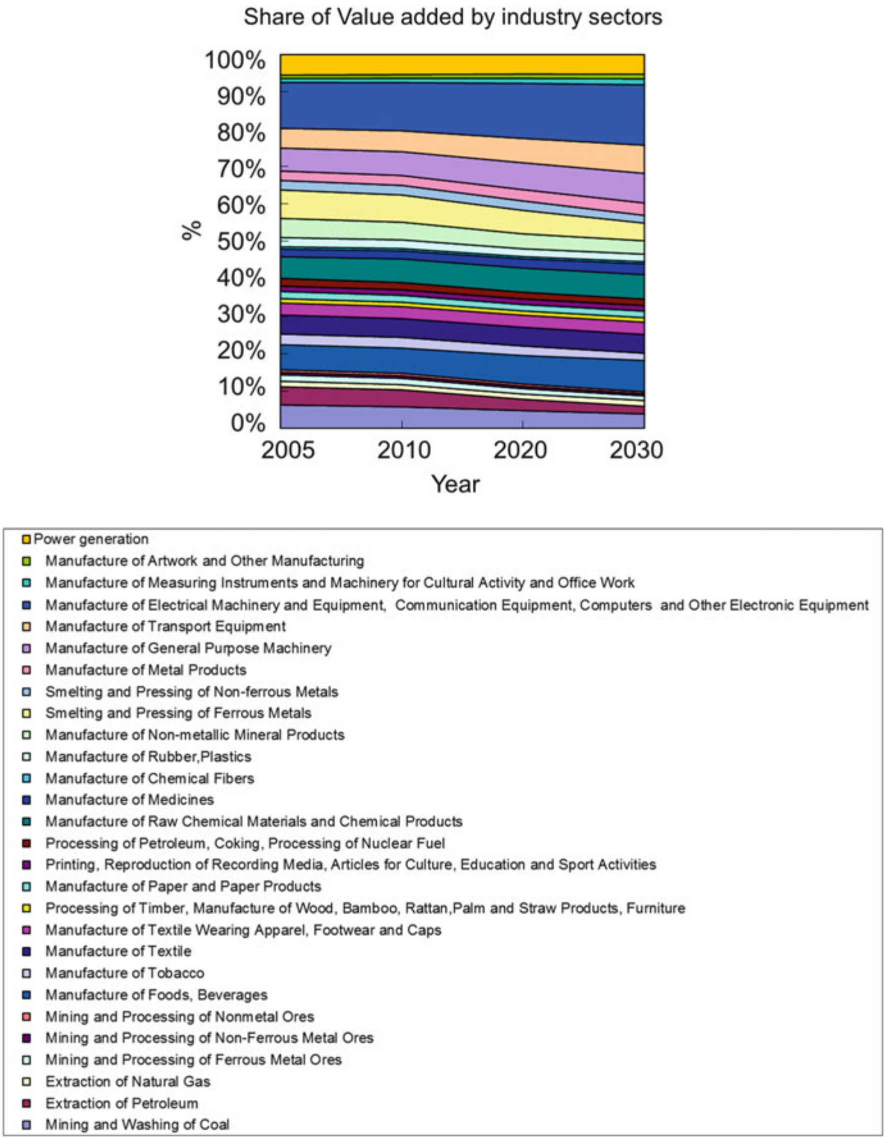

Fig. 2.5 Structural change in second industry (Source: Author's research result)

applied our own IPAC-SGM model to simulate structural change in secondary industry, as shown in Fig. 2.5.

The share of GDP from energy-intensive industry (middle part in Fig. 2.5) would reduce due to demand change. China's GDP will surpass that of the United States between 2020 and 2030, as such huge amount of GDP cannot rely on the existing economic trend involving heavy industry-driving development and raw material production. Based on a bottom-up study on the demand of energy-intensive products, it was found that many energy-intensive products will peak during 2020–2025, assuming that in the future the export of energy-intensive products will increase little, when it is already a major part of global output (see Table 2.1). This was learnt by looking at infrastructure development, including building construction, roads, railways, airports, etc., and final consumption needs, which consumed more than 95 % of cement and more than 55 % of steel (Kejun 2011). This analysis shows that the output of most of the energy-intensive products will peak before 2020.

Energy-intensive products consume nearly 50 % of energy in China, and provided that there is no significant increase in energy-intensive product production and that the growth rate thereof is much lower than GDP, the energy use increase associated with these energy-intensive products would also be limited. This would contribute greatly to decreased energy intensity per GDP and also contribute to reduced CO2 intensity.

As regards improving energy efficiency, during the 11th Five-Year Plan (2006–2010), energy efficiency was improved significantly (State Council 2011; Mark et al. 2010; Kejun 2009). In consideration of what occurred in energy efficiency during the 11th Five-Year Plan, and compared with energy conservation efforts over the last several decades and efforts made by other countries, China could be seen as having taken unprecedented action on energy conservation. Specifically, it:

- Made energy conservation policy one of the top national and top policy priorities.
- Made the energy intensity target a key indicator for local government officials.
- Involved a high number of new policies—nearly one a week from 2007 to 2008—on energy conservation from central government, in addition to local government energy policies.
- Initiated the Top 1000 Energy-Consuming Enterprise Programme, which focused on improving energy efficiency of China's largest 1000 companies which in total account for one third of China's total energy use.
- Closed small-sized power generation facilities and other industries, which was a bold measure that could have led to social unrest, unemployment and loss of profit for stockholders.

From the technical viewpoint, the above energy efficiency measures represent big achievements. China has released a total of 115 state key energy-efficient technology promotion catalogues in three batches and specially promoted seven energy-efficient technologies in the iron and steel, building material and chemical industries. Unit energy use per tonne of steel products, copper and cement decreased by 12.1 %, 35.9 % and 28.6 by 2010, respectively. By 2010, almost all advanced technologies on energy saving in industry were adopted in China. In the steel-making industry, the penetration of coke dry quenching (CDQ) increased from 30 % to more than 80 %. Use of top gas recovery turbines (TRT) increased from 49 to 597 sets. The share of furnaces with capacities above 1000 m^3 increased from

21 to 52 %. The share of new advanced rotary kilns in cement manufacturing increased from 39 to 81 %. The use of coke dry quenching in coke making increased from less than 30 % to more than 80 %. Heat recovery in cement manufacturing increased from nearly 0 to 55 %. Unit energy use for power generation supply decreased from 370 gce/kWh to 333 gce/kWh.

Owing to the widespread use of advanced high energy efficiency technologies, costs have been greatly reduced over the last several years—to the point at which some high energy efficiency technologies are even cheaper than old technologies, such as dry rotary kilns in the cement industry and super critical and ultra-super critical power generation technologies.

Such progress in energy efficiency improvements in China brings with it more opportunities for further steps in energy efficiency improvements, as follows:

- A deeper public and governmental understanding of the importance of energy efficiency. As discussed above, energy efficiency and conservation policies are one of the key issues in government—both national and local.
- Improvements in energy efficiency have been acknowledged as a means to increase economic competitiveness. Experience from other countries shows that higher energy efficiency is related to increased national economic competitiveness.
- Progress in technology towards high energy efficiency has led to new manufacturing markets for Chinese technologies. Lower cost, advanced technologies have already rapidly penetrated within China, which has profited industry. In the meantime, the international market also has a very large potential for new technologies, which will benefit not only the manufacturing industry but also energy efficiency improvements and GHG mitigation in developing countries.

It is anticipated for energy efficiency to continue improving from 2010 to 2020 in a similar manner in the 11th Five-Year Plan, based on the IPAC modelling results.

- Renewable energy development

China is the fastest-growing country for new energy and renewable energy. In order to improve the quality of the environment and promote new industry, China has extended great efforts to promote renewable energy, particularly over the past several years, and especially in wind and solar—from 2005 to 2010 the average annual growth rate exceeded 50 % annually (CEC 2011). Based on China's plans for renewable energy, by 2020 renewable energy will represent 15 % of total primary energy, which includes renewable energy not included in national statistics on energy, such as solar hot water heaters and rural household biogas digesters. Another related target is a share of non-fossil fuel energy of 15 % of the total primary energy by 2020, which includes both commercial renewable energy and nuclear energy.

- Nuclear energy development

It is expected that a nuclear energy installed capacity of over 58 GW will be realised by 2020 based on new nuclear planning, which is much larger than that original planned (40 GW).

Since the Fukushima nuclear accident in Japan, there has been much discussion on nuclear development in China; however, China has little choice in light of future power generation. Over the last several years, coal-fired power generation has increased rapidly, with an annual newly installed capacity of more than 60 GW. However, as is well known, compared to nuclear, coal-fired power generation causes high environmental and human damage. Based on the expected high demand due to energy use in China, by 2050 there is no future major role for renewable energy. Therefore, nuclear power generation will play an important role in China's future energy system by 2020.

– Carbon capture and storage (CCS)

China will have to use CCS for the next several decades if coal use continues on its present course. Even with the enhanced low-carbon scenario, coal use will be at around 1.8 billion tonnes by 2050. CCS is essential for China to enable deep cuts in CO2 emissions after 2030. Based on the study IPAC team involved for CCS implementation in China, the learning effect will have to be big to foresee the cost reduction in future. The total cost to apply CCS for 100 coal-fired power plants is not very high and will raise the price of grid electricity by 3 cent/kWh. In the enhanced low-carbon (ELC) scenario, CCS was adopted as one of the key mitigation options.

For CO2 emissions, removed CO2 emissions are given in Fig. 2.6. The key assumptions are given in Tables 2.2 and 2.3 (Kejun 2011). A lower removal rate for different power generation technologies is assumed because technological development is not yet mature at the beginning of adoption of CCS.

In the 2-degree scenario, compared with the enhanced low-carbon scenario, further implementation of renewable energy and replacing coal with natural gas were considered. For economic structural change, energy efficiency stays the same in the 2-degree scenario. Based on this, it is possible for China to peak in CO2 emissions before 2025 and then start deep cuts in CO2 emissions.

In the 2-degree scenario, renewable energy is much more extended from the enhanced low-carbon scenario. In the enhanced low-carbon scenario, power generation from renewable energy (including large hydro) will be around 34 %, and nuclear energy will account for 35 % by 2050. Installed capacity for wind, solar and hydro will be around 450 GW, 360 GW and 510 GW by 2050, respectively. In the 2-degree scenario, power generation from renewable energy could reach 48 % of the total power generation, leaving only 17 % for coal-fired power generation. Installed capacity for wind, solar and hydro is 930 GW, 1040 GW and 520 GW, respectively, by 2050.

Another key factor is the increasing use of natural gas in China. In the enhanced low-carbon scenario, natural gas use will be 350 BCM by 2030 and 450 BCM by 2050. In the 2-degree scenario, natural gas would be around 480 BCM by 2030 and 590 BCM by 2050. If natural gas is combined with renewable energy, coal use in

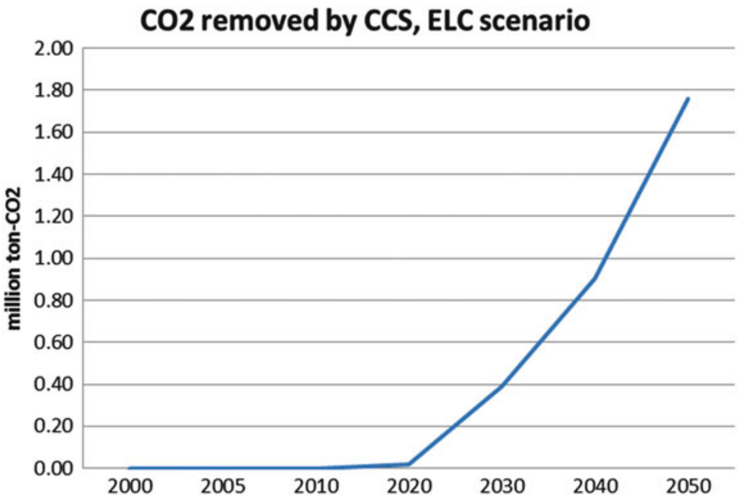

Fig. 2.6 CO2 removed by CCS in power generation sector (Source: Author's research result)

Table 2.2 Removal rate for CO2 by CCS in ELC scenario, %

	Super critical	US-critical	IGCC	IGCC fuel cell	NGCC
2020	80.0	80.0	85.0	85.0	85.0
2030	85.0	85.0	90.0	90.0	90.0
2040	85.0	85.0	90.0	90.0	90.0
2050	85.0	85.0	90.0	90.0	90.0

Source: Author's research result

Table 2.3 Power generation capacity with CCS in ELC scenario

	Super critical	US-critical	IGCC	IGCC fuel cell	NGCC
2020	0	0	1316	0	203
2030	217	379	6310	701	3411
2040	1319	2184	12,890	2275	9679
2050	2822	8465	22,045	5144	21,514

Source: Author's research result

China by 2050 will be lower than 1 billion tonnes. If so, CCS could be used for all coal-fired power plants and half of natural gas power plants.

Then, CO2 emissions in China could reach a peak before 2025, and the reduction in CO2 emissions by 2050 would be more than 70 % compared with that in 2020.

The renewable energy scenario in the 2-degree scenario is feasible owing to the recent progress in renewable energy development in China; the actual cost learning curve for wind and solar is much stronger than the model used. Technology perspective studies were also one of the key research areas in the IPAC modelling team, which has performed detailed analysis on selected technologies such as

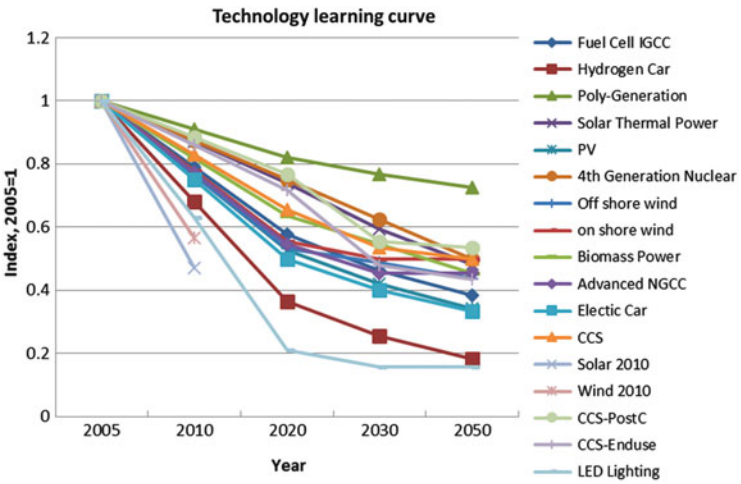

Fig. 2.7 Technology learning curve used in IPAC-AIM/technology model and data for 2010 (Source: Author's research result)

electric cars, nuclear energy, renewable energy and electric appliances (Kejun et al. 2009, 2012; Kejun 2011). Figure 2.7 presents the cost learning curve used in the model compared with actual data by 2010. Such technological progress results in a big drop in the cost of wind power and solar power within 2 years. Presently, in the coastal area, the cost of power generation for some wind farms can already compete with coal-fired power plants.

The progress in end-use technologies also moves faster than assumed by the model. Electric appliances such as LED TVs, higher-efficiency air conditioners and high-efficiency cars already had a higher penetration rate by 2011 than the model assumed. If policy is correct, a lower energy demand in the 2-degree scenario will be much more feasible by 2020 and after.

In the meantime, rapid GDP growth provides strong support for low-carbon development in China. In the 11th Five-Year Plan period (2006–2010), the annual GDP growth rate is 11.2 %, but is 16.7 % if calculated based on current value (China Statistic Yearbook 2013 2013). It is expected that by 2015, GDP in China could reach 75 trillion Yuan (at current value), newly added accumulated GDP will be 450 Trillion Yuan and cumulative GDP will be 860 Trillion Yuan. The investment needed in all modelled studies is very small compared with GDP and is normally 2–4 % or less. Regarding investment in China, new and renewable energy is one of the key sectors to be promoted within government policies and planning; thus there could be much more investment in renewable energy in the future, based on the fact that China was already the biggest investor in renewable energy as of 2010 and accounted for 24 % of the world's total.

Reviewing the progress in renewable energy planning in China, the target for renewable energy has been greatly revised upwards in recent years. Renewable

Energy Planning 2006 set the targets for wind at 30 GW and solar at 2 GW by 2020. By 2009 the National Energy Administration (NEA) announced that installed wind power generation will be 80 WG by 2020, and then in 2010 the NEA stated that installed wind power generation will reach 150 GW and solar at 20 GW by 2020. As of the end of 2011, targets for wind of 200 to 300 GW and solar of 50 to 80 GW were under discussion.

Based on the conclusion from Chinese Academy for Engineering, China's grid could adopt such renewable energy power generation in the short term.

2.3.1 Policy Options

In the modelling analysis, several policy options were simulated, one of the key ones being carbon pricing. Introducing carbon pricing, including a carbon tax or emission trading, could be an effective way to control CO2 emissions in China.

Another key policy option is setting more caps for CO2 emissions in China, which has been an effective way to limit CO2 emission increases in recent years.

2.4 Factors Causing Uncertainty in the Modelling Analysis

If we look at the scenarios, there are still several uncertainties in the emission path.

The biggest challenge is whether China's economic structure could be optimised and be directed away from a heavy industry-based and energy-intensive economy to a tertiary sector-based and less energy-intensive economy. By 2010, cement and steel output was 1.8 billion and 630 million tonnes, which is already higher than or close to the data in Table 2.2. Recently, the IPAC modelling team reanalysed the demand for cement and steel by using a methodology similar to energy forecasting, which reconfirmed the data in the table is the way for China to go. In recent years China has undergone a period of rapid infrastructure development, which cannot be sustained year-on-year going forwards. We have high confidence that many energy-intensive products will reach a peak in the near future, before 2015.

Another big uncertainty is whether the grid could adopt a large influx of renewable energy. Based on EU's experience to date, power generation from wind and solar could rise above 15 % of total power generation, and technological progress could potentially push the share of renewable energy power generation much higher (WWF 2010). However, based on the 2-degree scenario, by 2020 power generation from wind and solar in China still only accounts for 9 %.

2.5 Conclusions

If the global 2-degree target is to be implemented, China's CO2 emissions have to peak before 2025.

By using a detailed analysis modelling tool, it has been found that China could peak in CO2 emissions before 2025 and start deep cuts after that to a 70 % or greater cut by 2050 compared to 2020.

Meeting the 2-degree goal within the next 40 years will be challenging enough, and a reduction of such magnitude would require the near-simultaneous and successful deployment of all available low-carbon energy technologies and a high level of international cooperation. China will need to substantially exceed the government target announced in Copenhagen, but it is feasible if sufficient domestic action is taken and international collaboration takes place, and progress is made in technology. China's low-carbon development planning and effort should be encouraged in the future; a well-designed international regime aiming at a low-carbon pathway should be designed.

The study focus on a deep-cut emission scenario by region based on efforts and technological feasibility should be presented to show a possible future for reductions towards a 2-degree global target.

Renewable energy development policies are crucial for China to reach the 2-degree target; as with technological progress, much more renewable energy could be utilised in China. Further, China's energy system has to be diverse, and nuclear energy is still an important option due to its relative safety and low environmental impact, despite the recent developmental slowdown caused by the accident in Japan.

Carbon pricing could be introduced in the near future. It is hard to reflect shorter-term change but needs more policy support to make technology development.

Setting a cap for CO2 emissions in China has been an effective way to limit CO2 emission increases over recent years. China is now implementing cap setting on energy demand in its 12th Five-Year Plan, together with a target for non-fossil fuel energy by 2020, which will represent a good practice as regards setting up caps on CO2 emissions post-2015. In the meantime, China is implementing domestic emission trading in pilot cities and provinces that will be capped for emissions in the near future.

Specific policy recommendations are as follows:

- Place a high emphasis on optimising economic development. For a long time, China has announced its desire to adjust the economic development pattern away from heavy industry-based development to a service industry-based economy. However, little effective action has been taken. The newly announced 12th Five-Year Plan sets a GDP growth target of 7 %, which implies economic optimisation will occur. Recent government action favouring a lower economic development growth rate has started to produce results, and this action should be continued in the long term.

- Put in place a clear long-term target for CO2 emissions with specific total amount control (emission caps). China is currently attempting energy total amount control, which will provide a good basis for setting a target for total CO2 emission amount control. In this regard, setting long-term targets for CO2 emissions up to 2030 and 2050 would send a clear message that future CO2 emission reductions are being targeted.
- Introduce a carbon-pricing regime, such as carbon tax or emission trading, in the near future, to send a carbon-pricing signal. This will help push economic optimisation in the direction of a low-carbon economy.
- Make energy efficiency efforts deeper and wider ranging. Despite the huge achievements in energy efficiency in the 11th Five-Year Plan, there is still much more room for further action. Policies such as energy efficiency standards could be accelerated due to rapid progress in technologies.
- Make full support on renewable development, leave market for renewable energy development with support of feed-in tariff. Recently there has been discussion on limiting wind and solar energy, and this will obviously negatively impact on renewable energy development in China. There is plenty of space on the grid to adopt renewable energy in the future.
- Continue to support nuclear energy development and raise the security level of nuclear energy to provide cleaner energy. In China, nuclear power generation is still one of the cleanest and safest forms of energy supply compared to fossil fuel energy, which will continue to dominate China's energy system for decades. The strategy should be clear, involving more efforts to improve the technology.
- Initiate a pilot phase project as soon as possible for CCS in China. A plan should be made to have 7–10 CCS projects by 2020 to test the technology and make a decision on the best type. This will be crucial for expanding the utilisation of CCS projects post-2020.
- Do more for public awareness on low-carbon development; the public needs to be much more involved in low-carbon development as this could lead to reorientation of the manufacturing industry.

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Chapter 3
India's GHG Emission Reduction and Sustainable Development

P.R. Shukla and Subash Dhar

Abstract India has made voluntary commitment for reducing the emission intensity of GDP in the year 2020 by 20–25 % below that in the year 2005. The Indian approach is based on delineating and implementing cost-effective mitigation actions which can contribute to national sustainable development goals while remaining aligned to the UNFCCC's expressed objective of keeping the average global surface temperature increase to below 2 °C over the preindustrial average. This chapter assesses three emission scenarios for India, spanning the period 2010–2050. The analysis is carried out using a bottom-up energy system model ANSWER-MARKAL, which is embedded within a soft-linked integrated model system (SLIMS).

The central themes of the three scenario storylines and assumptions are as follows: first, a business-as-usual (BAU) scenario that assumes the socioeconomic development to happen along the conventional path that includes implementation of current and announced policies and their continuation dynamically into the future; second, a conventional low carbon scenario (CLCS) which assumes imposition, over the BAU scenario, of CO_2 emission price trajectory that is equivalent to achieving the global 2 °C target; and third, a sustainable scenario that assumes a number of sustainability-oriented policies and measures which are aimed to deliver national sustainable development goals and which in turn also deliver climate mitigation, resilience, and adaptation as co-benefits. The sustainable low carbon scenario (SLCS) also delivers same cumulative emissions from India, over the period 2010–2050, as the CLCS scenario using carbon price as well as a mix of sustainability-oriented policies and measures.

The scenario analysis provides important information and insights for crafting future policies and actions that constitute an optimal roadmap of actions in India which can maximize net total benefits of carbon emissions mitigation and national sustainable development. A key contribution of the paper is the estimation of the net social value of carbon in India which is an important input for provisioning carbon finance for projects and programs as an integral part of financing NAMAs.

P.R. Shukla (✉)
Indian Institute of Management, Ahmedabad, India
e-mail: shukla@iimahd.ernet.in

S. Dhar
DTU – Dept. Management Engineering, UNEP-DTU Partnership, Copenhagen, Denmark

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The analysis in the paper will be useful for policymakers seeking to identify the CO_2 mitigation roadmap which can constitute an optimal mix of INDCs for India.

Keywords Climate agreement • Sustainable development • Scenario modeling • Mitigation options • CO_2 Price • Social cost of carbon • $PM_{2.5}$ emission

Key Message to Policymakers

- India's CO_2 intensity declines in BAU yet inadequate for global low carbon goal.
- Carbon price affects energy supply side and leads to high share of nuclear energy and CCS.
- Sustainability policies reduce energy demand and enhance share of renewables.
- Low carbon policies aligned to sustainability goals deliver sizable co-benefits.
- Sustainability scenario delivers same carbon budget with lower social cost of carbon.

3.1 Introduction

India has endorsed the long-term target of limiting the temperature rise to under 2 °C (GoI 2008) and has also made voluntary commitment for reducing the emission intensity of GDP in the year 2020 by 20–25 % below that in the year 2005 at COP15 in Copenhagen. The "National Action Plan on Climate Change (NAPCC)" released by the Prime Minister's Office in June 2008 considers mitigation and adaptation actions implemented through eight National Missions (Table 3.1) to which the current government has added four more missions: wind, waste to energy for mitigation, and coastal and human health for adaptation.

The Indian approach to climate change is based on delineating and implementing cost-effective mitigation actions which can contribute to national sustainable development goals while remaining aligned to the UNFCCC's expressed objective of keeping the average global surface temperature increase to below 2 °C over the preindustrial average.

3.2 Model and Scenarios

3.2.1 *Assessment Methodology and Model System*

The integrated framework proposed in Fig. 3.1 falls under the earlier AIM family of models (Kainuma et al. 2003; Shukla et al. 2004). The bottom-up analysis is done

Table 3.1 Eight National Missions for climate change

Sr. No.	National mission	Targets
1	National solar mission	Specific targets for increasing use of solar thermal technologies in urban areas, industry, and commercial establishments
2	National mission for enhanced energy efficiency	Building on the energy conservation Act 2001
3	National mission on sustainable habitat	Extending the existing energy conservation building code, integrated land-use planning, achieving modal shifts from private to public transport, improving fuel efficiency of vehicles, alternative fuels, emphasis on urban waste management and recycling, including power production from waste
4	National water mission	20 % improvement in water use efficiency through pricing and other measures
5	National mission for sustaining the Himalayan ecosystem	Conservation of biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers are projected to recede
6	National mission for a "Green India"	Expanding forest cover from 23 to 33 %
7	National mission for sustainable agriculture	Promotion of sustainable agricultural practices
8	National mission on strategic knowledge for climate change	The plan envisions a new Climate Science Research Fund that supports activities like climate modeling and increased international collaboration; it also encourages private sector initiatives to develop adaptation and mitigation technologies

by the MARKAL model (Fishbone and Abilock 1981). MARKAL is an optimization mathematical model for analyzing the energy system and has a rich characterization of technology and fuel mix at end-use level while maintaining consistency with system constraints such as energy supply, demand, investment, and emissions (Loulou et al. 2004). The ANSWER-MARKAL model framework has been used extensively for India (Shukla et al. 2008, 2009; Dhar and Shukla 2015).

AIM/CGE and GCAM are top-down, computable general equilibrium (CGE), models used to compute the GDP loss and CO_2 price for the 2 °C stabilization scenario. AIM/CGE has been developed jointly by the National Institute for Environmental Studies (NIES), Japan, and Kyoto University, Japan (AIM Japan Team 2005). The model is used to study the relationship between the economy and environment (Masui 2005).

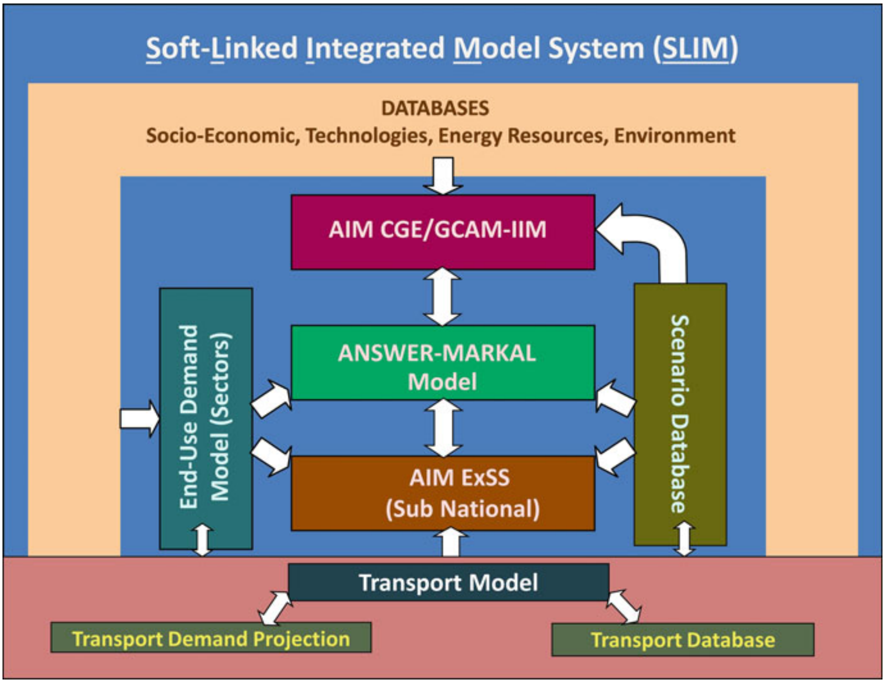


Fig. 3.1 Integrated model system

3.2.2 Scenarios Description

3.2.2.1 Business-as-Usual (BAU) Scenario

The BAU scenario considers the future economic development will copy the resource-intensive development path followed by the developed countries. The annual GDP growth rate is 8 % for the 17 years (2015–2032) and matches with the economic growth projections for India (GoI 2006, 2011). The GDP growth is expected to slow down post 2030, and the growth for overall scenario horizon, i.e., 2010–2050, is at a CAGR of 7 %. The rate of population growth and urbanization follows the UN median demographic forecast (UNPD 2013), and accordingly, the overall population is expected to increase to 1.62 billion by 2050. This scenario assumes a weak climate regime, and a stabilization target of 650 ppmv CO_2e is considered. The carbon price rises to a modest to \$20 per ton of CO_2 in 2050 (Shukla et al. 2008).

3.2.2.2 Conventional Low Carbon Scenario (CLCS)

This scenario considers a strong climate regime and a stringent carbon tax post 2020. The underlying structure of this scenario is otherwise similar to the BAU. The scenario assumes stabilization target of 450 ppmv CO_2e. The CO_2 price trajectory assumes implementation of ambitious Copenhagen pledges post 2020, and CO_2 price trajectory therefore is below 15 US $ per t CO_2 till 2020 and then increases steadily to reach 200 US $ per t CO_2 by 2050 (Lucas et al. 2013). The scenario assumes greater improvements in the energy intensity and higher share of wind and solar renewable energy compared to the BAU scenario.

3.2.2.3 Sustainable Low Carbon Scenario (SLCS)

This scenario follows the "sustainability" rationale, similar to B1 global scenario of IPCC (2000). The scenario assumes decoupling of the economic growth from resource-intensive and environmentally unsound conventional path of the BAU. The scenario seeks to achieve by significant institutional, behavioral, technological (including infrastructures), and economic measures promotion of resource conservation, energy conservation, dematerialization, and demand substitution (e.g., telecommunications to avoid travel). The scenario also considers a strong push for exploitation of large renewable energy potential (GoI 2015) and increased regional cooperation among countries in South Asia (Shukla and Dhar 2009) for energy and electricity trade and effective use of shared water and forest resources.

The scenario considers socioeconomic and climate change objectives and targets (Fig. 3.2). The SLCS considers a strong climate regime and climate objective similar to CLCS. The SLCS considers a CO_2 budget equivalent to CLCS for the period 2010–2050. However, since CO_2 mitigation is a co-benefit of a number of sustainability actions, the social cost of carbon is expected to be lower than CLCS (Shukla et al. 2008).

3.3 Scenarios Analysis and Comparative Assessment

3.3.1 Energy Demand

The overall demand for energy in the BAU is expected to increase 3.6 times from 2011 to 2611 Mtoe in 2050. The compounded annual growth rate (CAGR) is 3.6 % for the period 2011–2050 which is slower than average GDP growth of 7.0 % which has been assumed for the economy. The decoupling between GDP and energy use is due to both structural changes within the economy (greater share of service sector) and improvement in technological efficiencies. The technological efficiency

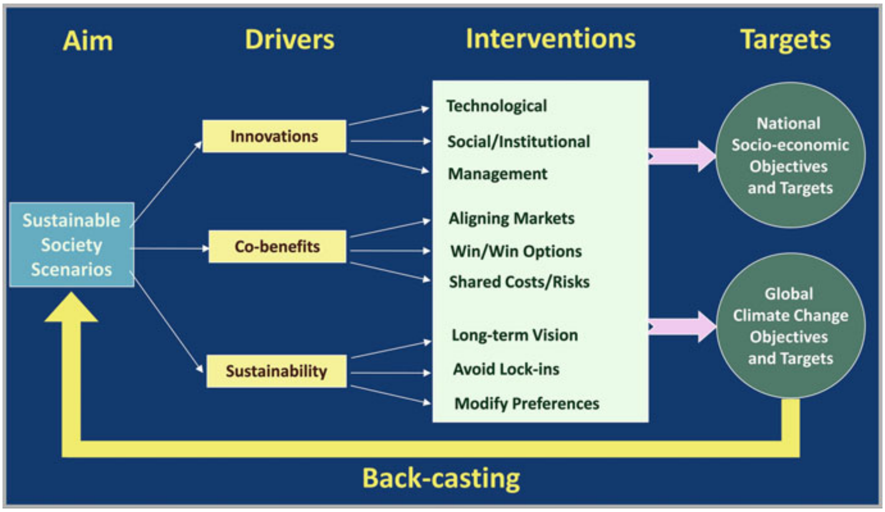


Fig. 3.2 Framework for the SLCS

improvement is most significant in the power generation where the net efficiencies improve from around 31.6 % to around 39 % in 2050.

The fuel mix is diversified in the BAU with nuclear energy, gas, and renewables taking a larger share of energy (Fig. 3.3). Coal however continues to remain the mainstay in the BAU scenario, and the bulk of coal is taken for power generation. Coal-based power generation capacity is expected to increase from 117 GW to 700 GW. Nuclear energy takes the next largest share of incremental demand for power generation, and by 2050 the installed capacity for nuclear energy is expected to increase to 200 GW from only 5 GW in 2010.

In the CLCS scenario, high carbon prices are able to bring down overall demand for energy in the medium term (by 2030); however, in the long term, the energy demand is only marginally lower than BAU (Fig. 3.4). A key reason for this is the large penetration of carbon capture and storage (CCS) in combination with coal-based power generation and steel production. CCS technology requires energy for CO_2 collection, transportation, and pumping into the storage and therefore imposes an energy penalty. The fuel mix is however diversified in a much stronger fashion with reference to the BAU, and the share of nuclear energy and renewables is much higher (Fig. 3.5).

In the SLCS energy demand is much lower (Fig. 3.4) since the demand for steel, cement, fertilizers, and many other energy-intensive commodities is much lower than BAU due to resource conservation and dematerialization. The energy demand is also lower from building, transport, and commercial sectors due to sustainable lifestyles. By 2050 the overall demand for energy is around one third lower than BAU. The fuel mix is also diversified; however, unlike CLCS, the reliance on nuclear energy and CCS is minimal and consistent with concerns with regard to their sustainability.

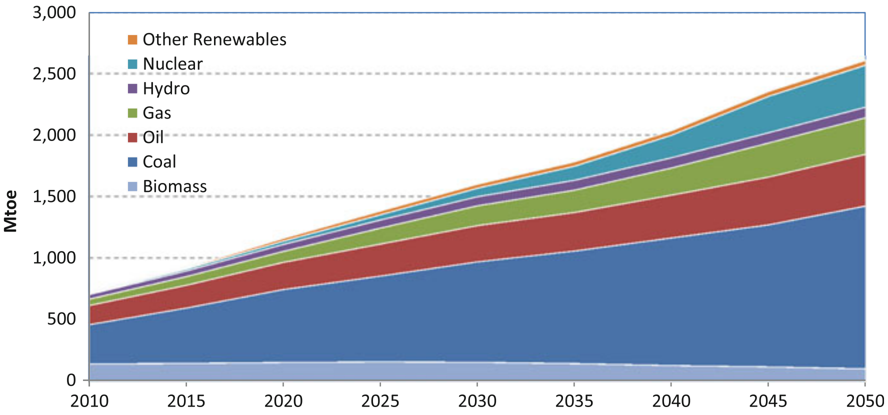


Fig. 3.3 Primary energy fuel mix and demand in the BAU

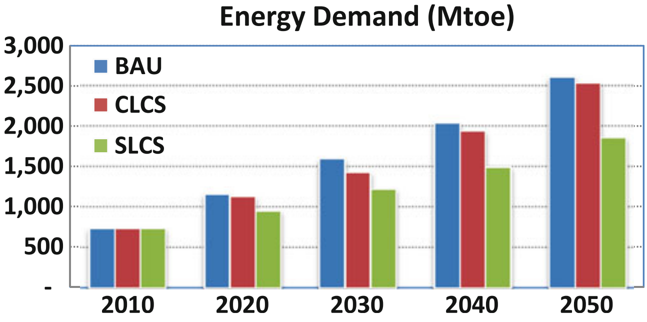


Fig. 3.4 Total primary energy demand in the BAU and low carbon scenarios

3.3.2 CO_2 Emissions and Mitigation Options

The CO_2 emissions from the energy use in the BAU increase 3.8 times between 2010 and 2050 and reach 7.32 billion tCO_2 in 2050. On a per capita basis, the emissions would be around 4.5 tCO_2 which is close to the current global average (IEA 2013). The bulk of the CO_2 emissions currently are attributable to the combustion of coal (Fig. 3.6), and this scenario would continue in the BAU in the absence of any strong climate policies.

Under both the low carbon scenarios, the growth in emissions can be limited (Fig. 3.7). In the conventional scenario, this is achieved by a small drop in energy demand (Fig. 3.4) and a sharp reduction in the share of coal from 51 % in BAU to 28 % in 2050 (Fig. 3.5). Coal is mainly substituted by nuclear energy and renewables. The share of renewable energy in 2050 is more than double from 9 % in BAU to 20 % in the CLCS (Fig. 3.5). Similarly, the share of nuclear energy is 23 % in 2050 in the CLCS. In addition coal use is increasingly decarbonized within power and steel sector with the introduction of carbon capture and storage (CCS). The total

Fig. 3.5 Fuel mix in low carbon scenarios in 2050

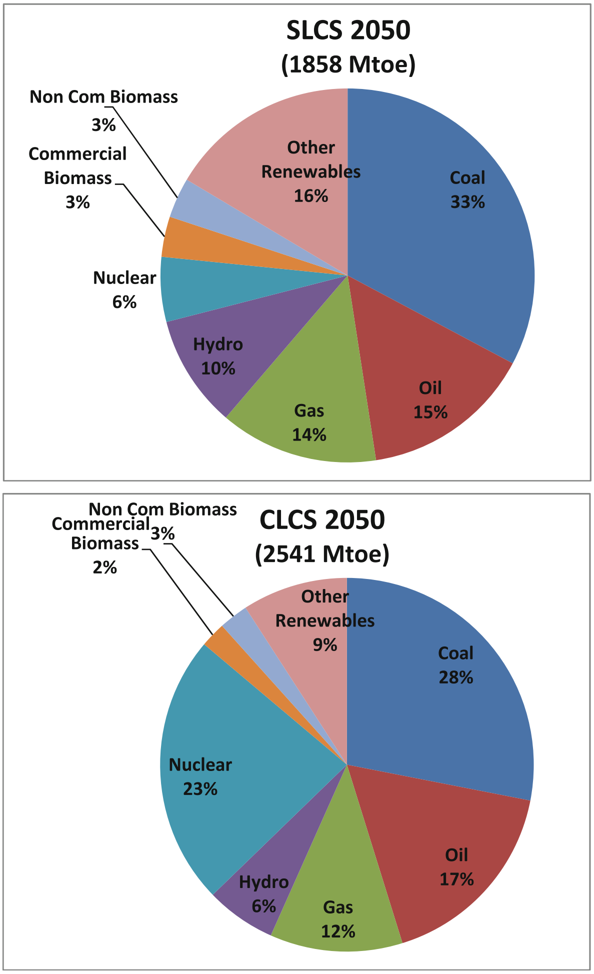


Fig. 3.6 CO_2 emissions in the BAU from energy use (million tCO_2)

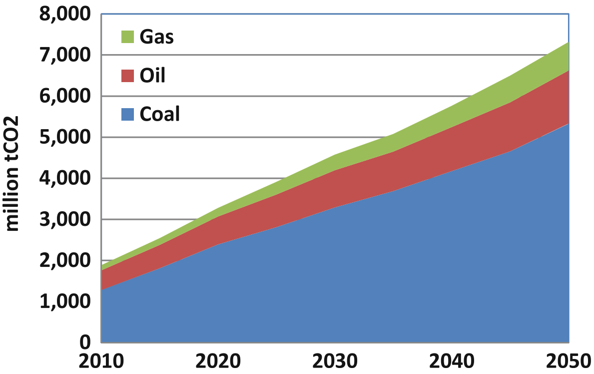
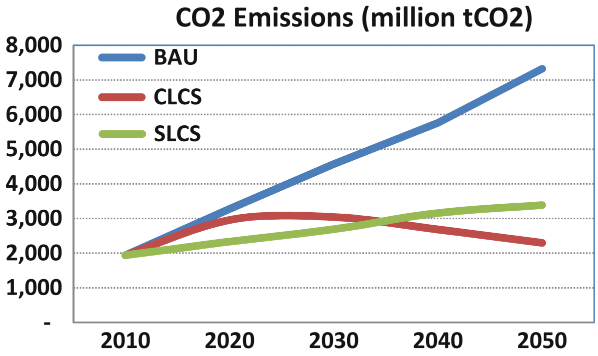


Fig. 3.7 CO_2 emissions in the BAU and low carbon scenarios from energy use (million tCO_2)



amount of CCS that is sequestered till 2050 is 30.6 billion tCO_2. A storage of less than five billion tCO_2 is available within depleted oil and gas fields and in coal mines (Holloway et al. 2009), and at many locations, this would be proximal to large point source (Garg and Shukla 2009). The supply curve for CCS therefore allows mitigation at costs below US $ 60 per tCO_2 within power and steel sector for a cumulative storage of 5 billion tCO_2. Beyond this, we have considered saline aquifers in the sedimentary basin as an option, though there is not much research or government initiative at the moment to identify potential and sites for this. Therefore, increasing CO_2 price was considered for this CO_2 storage.

In the SLCS scenario, emissions are lower due to a much lower energy demand (Fig. 3.4) from BAU. The lower energy demand is due to a wide variety of measures related to sustainability which reduce demand for energy-intensive industries like steel, cement, bricks, aluminum, etc. The second major driver is renewable energy which provides for one third of primary energy.

3.4 Co-benefits of Mitigation

Climate change mitigation can deliver co-benefits or co-costs, and we examine the scenarios on two indicators: energy security and local environment.

3.4.1 Energy Security

Energy security has been defined as the risk to the country from negative balance of energy trade and risks due to supply (Correlje and van der Linde 2006). In this sense a reduction in demand for fuel or increase in diversity of supply (Dieter 2002) is good for energy security. In terms of overall demand, the CLCS has almost similar demand as the BAU, whereas in case of SLCS, the overall demand is only 71 % of BAU in 2050 (Fig. 3.8). The fossil fuel use declines in the CLCS scenario; however,

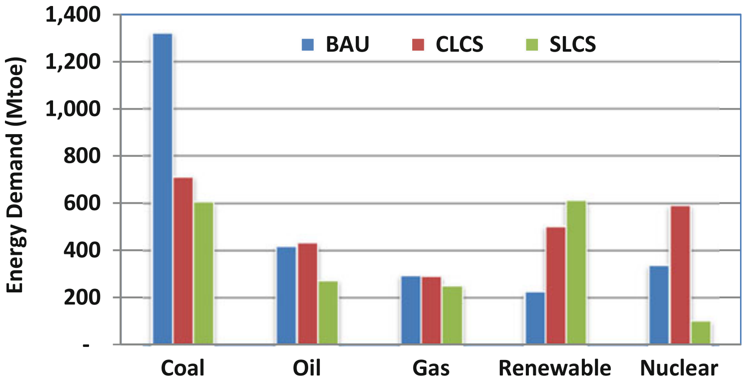


Fig. 3.8 Primary energy mix in 2050: BAU and low carbon scenarios

this is mainly due to a halving of demand for coal. Since India has a good resource availability for coal, the improvement in energy security would be small. In the SLCS scenario, the fossil fuel demand is lower for all fuels including oil, and since India depends for more than 80 % on imports of oil, improvements in energy security would be substantial. Indian nuclear energy establishment has propounded development of nuclear energy power using indigenously available thorium in the past (Kakodkar 2006); however, with signing of agreement with the nuclear energy suppliers group in 2008, India is able to import uranium. The planned nuclear energy power plants are all based on conventional fuel cycle with dependence on uranium, and therefore, higher nuclear energy will deteriorate energy security in the CLCS. In comparison the SLCS has a much lower share of nuclear energy which would help in improvement of energy security.

3.4.2 Environment

Many Indian cities have the very high levels of air pollution (WHO 2014) which is leading to serious health impacts (a. $PM_{2.5}$ is one of the key local pollutants and is responsible for severe health risks. Transport sector accounts for 30–50 % of the $PM_{2.5}$ (Guttikunda and Mohan 2014), and therefore, we analyze $PM_{2.5}$ for transport sector.

In India Bharat Stage III emission standard for motor vehicle (equivalent to Euro III) is applicable across India, and BS IV emission standards are applicable in the National Capital Region of Delhi and 20 other larger cities. Thirty additional cities are planned to move to Euro IV by 2015 (GoI 2014). In all the three scenarios, it is assumed that the BS IV would be fully implemented by 2020 all across India (GoI 2014).

The implementation of stricter emission norms which will entail changes to both vehicles and fuels will deliver for environment in the medium term (post 2025

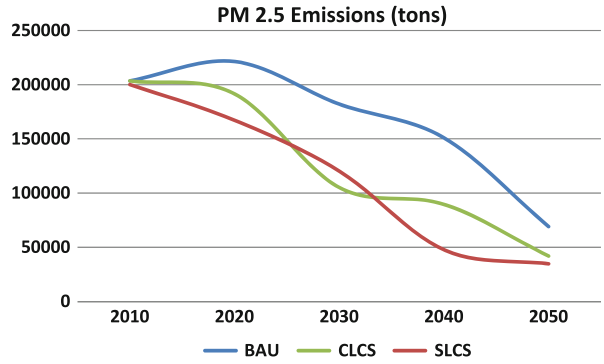


Fig. 3.9 PM 2.5 emissions from transport sector across scenarios

onwards); however, air pollution would remain a challenge for the next 10 years. However, strong sustainability measures as envisaged in SLCS can help in turning the tide on air pollution quite early (Fig. 3.9). Similarly, a strong climate regime can also bring significant benefits for air quality (Fig. 3.9).

3.4.3 Net Social Cost of Carbon

The CO_2 mitigation is the same between the two low carbon scenarios. In conventional scenario, the mitigation actions are mainly a consequence of a high carbon price which increases rapidly post 2020 and with an expectation of a good climate treaty in 2015. The advance measures taken as a part of the sustainability paradigm can help to put the country on a trajectory where CO_2 mitigation is a co-benefit and, because of this, the society can achieve a similar amount of mitigation at a lower social cost of carbon (Fig. 3.10). This means if sustainability is limited to India, a higher mitigation corresponding to the global carbon price will occur, which can then be traded. If the sustainability paradigm is global, then a mild tax trajectory (Fig. 3.10) is required.

3.5 Conclusions

The chapter presented historical projections of energy and emissions in India under different scenarios. The approach followed in this paper visualizes low carbon transition in India from two different perspectives. First is the conventional perspective which assumes the rest of the economy is in competitive equilibrium. The approach visualizes carbon mitigation as an outcome of the application of a globally efficient carbon price in the form of a tax or a shadow price resulting from the global emissions carbon cap. This perspective, referred to as conventional low carbon scenario (CLCS), however discounts the fact that developing country

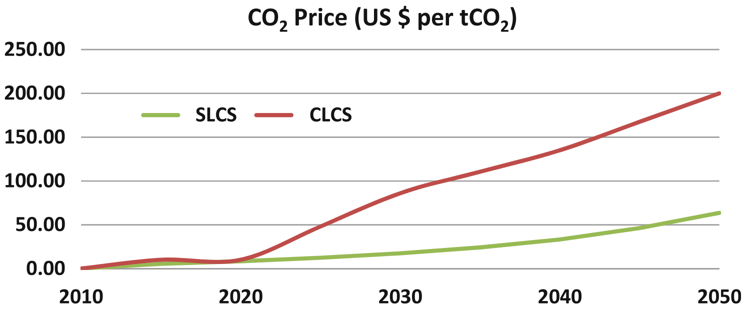


Fig. 3.10 Net social cost of carbon

economies have deep-rooted institutional weaknesses which impedes competitive behavior. The paper proposes a second scenario, referred to as sustainable low carbon scenario (SLCS), that explicitly recognizes the market weakness and hence explicitly implement additional policies which align the national sustainable development goals with the global low carbon objective.

As a reference point for the low carbon pathway, a business-as-usual (BAU) scenario is also assessed. A notable result is that energy demand and CO_2 emissions in India decouple significantly from GDP growth even in the BAU. However, the decoupling of CO_2 is not adequate when compared to what would a cost-effective global carbon regime targeting 2 °C temperature stabilization. Thus, further carbon mitigation is needed to align India's mitigation target with global stabilization.

Under CLCS, the application of global carbon price has little impact on energy demand, but it results in greater energy supply-side response like higher share of nuclear energy power and CCS. The projections show that by 2050, India can deploy nearly 30 billion tCO_2 sequestration capacity under CCS. This is much higher than what is available in depleted oil and gas wells and coal mines, and using this capacity at higher end can be extremely risky due to the uncertainty of the CCS capacity and costs in India. This aside, in this scenario, nuclear energy would supply nearly a quarter of the primary energy demand in 2050. This is also a high risk proposition given the uncertainty of the full cost of nuclear energy in India.

Under the SLCS, many sustainable development-focused measures such as designing and implementing sustainable habitat and mobility solutions, 3R (reduce, reuse, recycle) measures, and demand-side energy and resources management measures result in reducing the energy demand by a third in 2050. In addition, the policy support for renewable energy results in relatively minimal use of CCS which can be easily sequestered within the depleted oil and gas wells or coal mines in the country. The demand for nuclear energy power is also reduced significantly under this scenario. Solar and wind energy would play a bigger role in both CLCS and SLCS (Fig. 3.8). The energy security benefits, compared to BAU, are very high in SLCS but negligible in CLCS. Air quality benefits are high in both CLCS and SLCS.

In case of CLCS, the mitigation is achieved by applying the global carbon price over Indian economy. In case of SLCS, the emissions budget is assumed to be the same as the emissions in CLCS during the period 2010–2050. In SLCS, the emissions are at first reduced by various measures targeted to achieve national sustainable development goals. The budgeted carbon pathway is achieved by the shadow price of carbon corresponding to the budget constraint. This cost, which we refer to as the "social cost of carbon," is much lower in the case of SLCS since the carbon reduction that is delivered by the sustainability measures is assumed to be "free" since their cost is included in the cost-benefit assessment of national sustainability measures which typically do not include carbon benefits.

The assessment in the paper shows that aligning actions toward India's low carbon pathway with measures for achieving national sustainable development goals would result in significantly lower social cost of carbon for India. This signifies the existence of sizable co-benefits between low carbon and sustainable development actions. The methodology and analysis in this paper thus provides a way forward for scientifically delineating the Intended Nationally Determined Contributions (INDCs) for mitigation. The technological and financial details underlying the modeling analysis can be useful for preparing the road map of India's Nationally Appropriate Mitigation Actions (NAMAs) and downscale these to actionable projects with clearly identified pathways for technology development, transfer and deployment, as well as access to carbon finance.

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Chapter 4
Eighty Percent Reduction Scenario in Japan

Toshihiko Masui, Ken Oshiro, and Mikiko Kainuma

Abstract Toward the achievement of the 2 °C target, Japan has set several GHG mitigation targets after ratifying the Kyoto Protocol. In 2008, in order to discuss the GHG mitigation target in 2020 at COP15 held in Copenhagen, the committee on the mid- and long-term target in Japan was organized at the Cabinet Secretariat. At that discussion, the proposed six options were quantified, and finally, 15 % reduction in 2020 compared with 2005 level was selected as a target.

Because of the change of government, the new mitigation target in 2020, 25 % reduction compared to 1990, was announced at the United Nations Climate Change Summit in 2009. Then, the road maps to achieve this 25 % reduction target were quantified at the Central Environment Council. But just after they completed the road maps to achieve the target, the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident happened on March 11, 2011. Due to the nuclear power accident, the GHG mitigation road map and the future energy mix should be reconsidered. In 2012, the Energy and Environment Council forecasted that the GHG emissions in 2020 would be 5–9 % reduction compared to the 1990 level in the case of the prudent economic growth case.

After the change of government again, at the COP19 of UNFCCC in Warszawa in 2013, the new GHG mitigation target in 2020 was announced to be 3.8 % reduction compared to the 2005 level under the assumption of the no nuclear power supply. And in 2015, the mitigation target in 2030 was proposed to 1.042 GtCO2, that is, 26.0 % reduction compared to the 2013 level.

On the other hand, in the 4th Environmental Basic Plan endorsed by the Cabinet in 2012, the 80 % reduction of the GHG emissions was written clearly. In this paper, in order to assess the feasibility of this 2050 target, we utilized the AIM/Enduse to disaggregate Japan into 10 regions. The treated technologies include renewable

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T. Masui (✉)
National Institute for Environmental Studies, Ibaraki, Japan
e-mail: masui@nies.go.jp

K. Oshiro
Mizuho Information and Research Institute, Tokyo, Japan

M. Kainuma
National Institute for Environmental Studies, Ibaraki, Japan

Institute for Global Environmental Strategies, Kanagawa, Japan

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energy technologies, carbon capture and storage (CCS), and energy-saving technologies. The study shows that it is feasible to achieve 80 % emission reduction in Japan even without nuclear power. The impact of nuclear phaseout as compared to the illustrative scenario is relatively small in the long term because of the small share of nuclear energy in 2050 in any case. Achieving long-term emission reduction target proves to be still feasible with substantial increase of renewable energy, particularly solar PV and wind power. The share of renewable energy in electricity supply reaches approximately 85 % in 2050, and variable renewable energies account for about 63 % in electricity generation in 2050, hence imposing a further challenge for integration into the electricity system.

The feature of mitigation target in Japan is mainly based on the bottom-up approach. That is to say, the process stressed the feasibility of the target. On the other hand, the top-down decision is also requested for the ambitious reduction target. Toward the achievement of 2 °C target, taking actions with the long-term perspective becomes more important.

Keywords Mitigation • Carbon dioxide • 2 °C target • Energy mix • Electricity • Enduse model • Japan • Nuclear power • Carbon capture and storage

Key Message to Policy Makers

- Japan’s mitigation target in 2050 is set to be by 80 % reduction by the 4th Environmental Basic Plan.
- The existing target is set based on the available technologies, that is to say, the bottom-up approach.
- Top-down decision is also requested for the ambitious reduction target.
- The options to achieve the ambitious target have been available.

4.1 Introduction

In 2013 and 2014, the IPCC 5th Assessment Reports were approved. In this report, it is concluded that “It is extremely likely that human influence has been the dominant cause of observed warming since the mid-20th century” (IPCC 2013). The IPCC 5th Assessment Report mentions that, in order to achieve the 2 °C target, which is to limit the increase in global mean surface temperature to less than 2 °C, the GHG emissions in 2050 and 2100 will have to be reduced by 41–72 % and 78–118 %, respectively, compared with the 2010 level (IPCC 2014). Figure 4.1 shows the future GHG emissions, and the right blue range (430–480 ppmCO_2eq) is the emission pathways to achieve the 2 °C target likely.

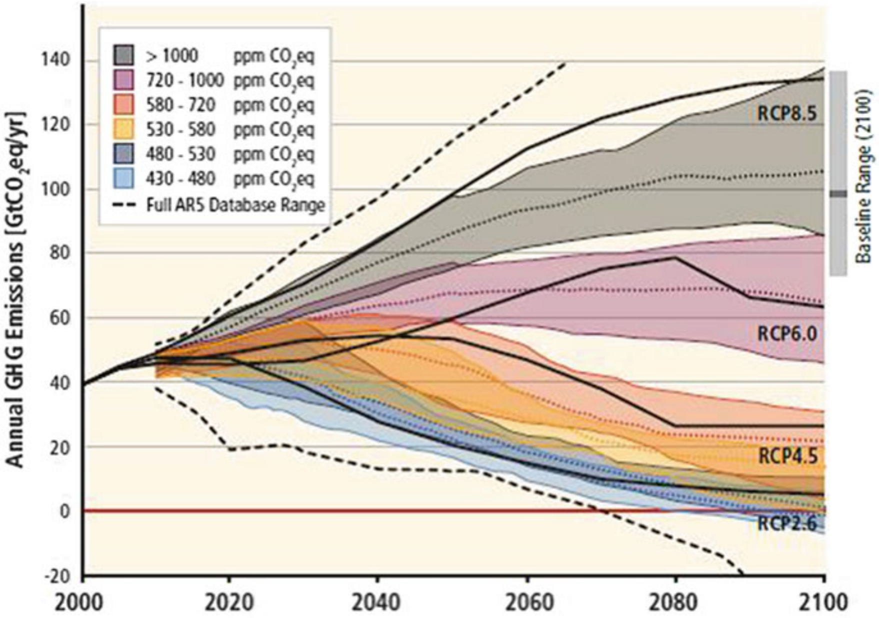


Fig. 4.1 Total GHG emissions in all IPCC AR5 scenarios

Toward the achievement of the 2 °C target, Japan has set several GHG mitigation targets after ratifying the Kyoto Protocol. In the following sections, mitigation target will be discussed and the quantification figures using the AIM (Asia-Pacific Integrated Model) are explained.

4.2 From the Kyoto Protocol to Middle-Term Target

Figure 4.2 shows the trend of GHG emissions in Japan from 1990 to 2013. The actual GHG emissions during the 1st commitment period in Japan exceeded the emission target set by the Kyoto Protocol, but if the effects of carbon sink and Kyoto Mechanism such as mitigation outside of Japan are taken into account, the emissions in Japan could achieve the emission target. On the other hand, the trend of GHG emission after 2010 would increase because of the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident in March 2011. Figure 4.3 shows the sectoral GHG emissions in Japan. Among the sectors, the emissions from commercial and residential sectors increased after the nuclear power plant accident.

In 2015, the COP21 of UNFCCC will be held in Paris. At this meeting, the post-2020 target will be discussed. Prior to the COP21, INDCs (Intended Nationally Determined Contributions), that is to say, the new ambitious target of GHG emission reduction, will be announced by each country by March 2015. Japan has been discussing this issue under the joint committee between the Ministry of the

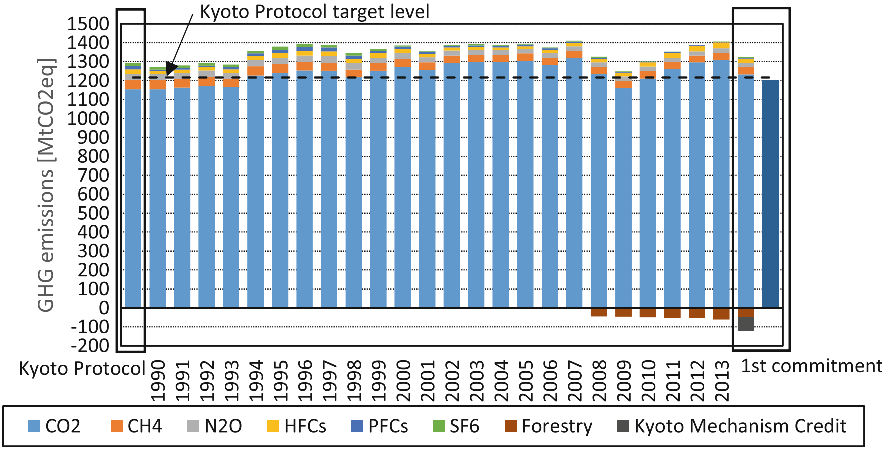


Fig. 4.2 GHG emissions from 1990 and Kyoto target (Data source: GIO 2014, 2015)

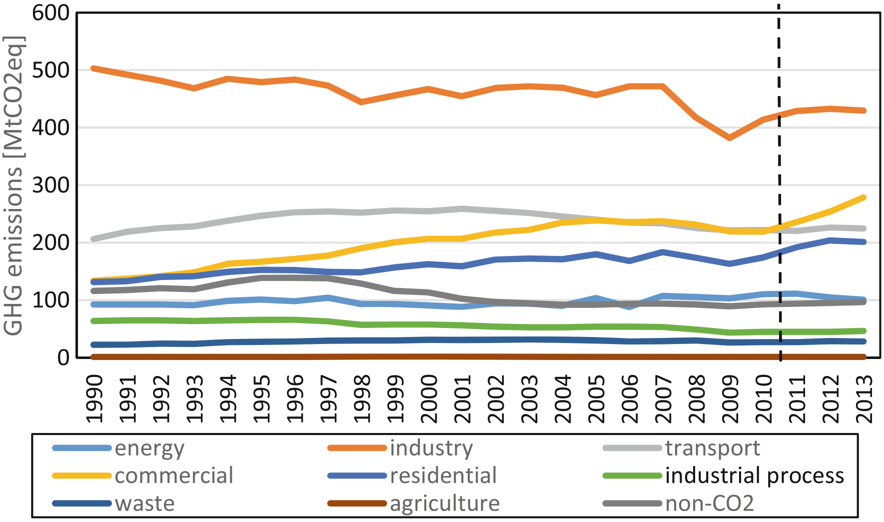


Fig. 4.3 Sectoral GHG emissions in Japan (Data source: GIO 2015)

Environment and Ministry of Economy, Trade and Industry. On April 30, the new GHG mitigation target in 2030 was announced by the government. The value is 1.042 $GtCO_2eq$, and this is 26.0 % reduction from the 2013 level. If the base year is set to 2005, the value of the reduction target becomes 25.4 %. The outline of the mitigation target in Japan in 2030 is introduced in Table 4.1.

The GHG mitigation targets in Japan have been changed when the government was changed. In 2008, in order to discuss the GHG mitigation target in 2020 at COP15 held in Copenhagen, the committee on the mid- and long-term target in Japan was organized at the Cabinet Secretariat. At that discussion, three types of

Table 4.1 Mitigation target in Japan in 2030

Unit: $MtCO_2eq$	Emissions in 2030	Emissions in 2005	Emissions in 2013
CO2 from energy combustions	927	1219	1235
Industry	401	457	429
Commercial	168	239	279
Residential	122	180	201
Transportation	163	240	225
Energy	73	104	101
Nonenergy CO_2	70.8	85.4	75.9
CH_4	31.6	39.0	36.0
N_2O	21.1	25.5	22.5
HFCs	21.6	12.7	31.8
PFCs	4.2	8.6	3.3
SF_6	2.7	5.1	2.2
NF_3	0.5	1.2	1.4

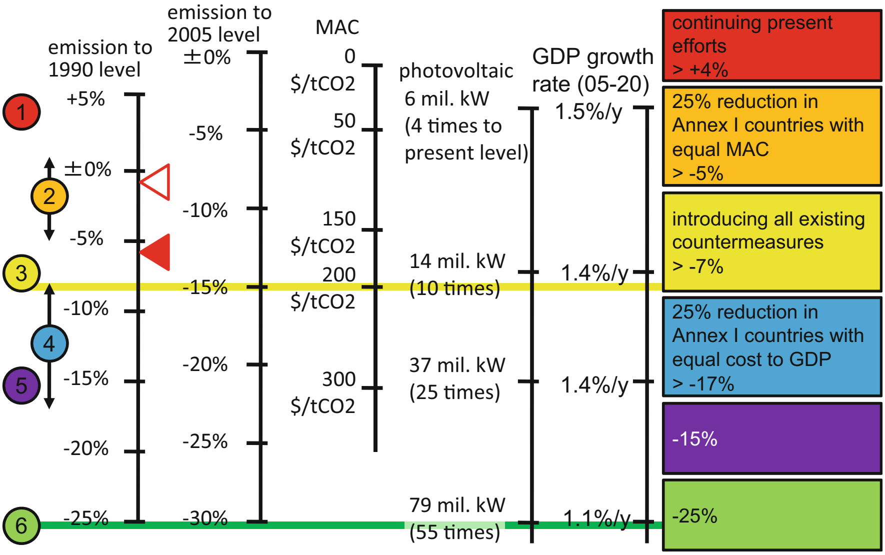


Fig. 4.4 Six options discussed in FY 2008 to FY 2009 (Note: The *red triangle* shows the mitigation target of all greenhouse gas emissions by the Kyoto Protocol. The *white triangle* shows the mitigation target of CO2 emissions from energy use)

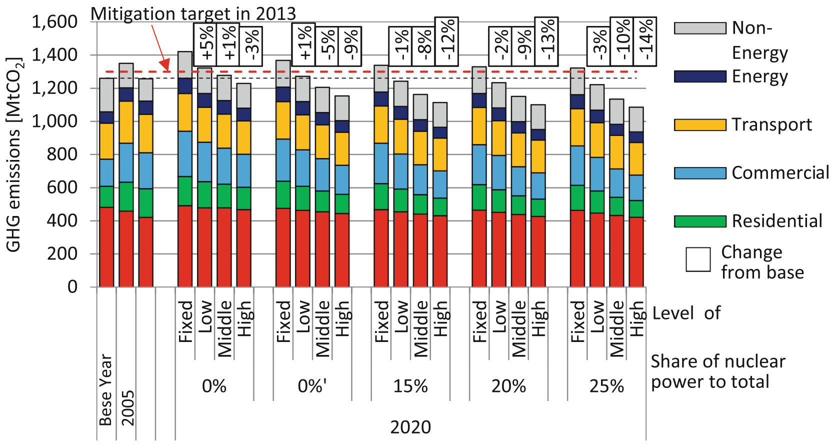
models were utilized, global enduse model, Japan enduse model, and Japan economic model, and the proposed six options were quantified. Finally, 15 % reduction in 2020 compared with the 2005 level was selected as a target by former Prime Minister Mr. T. Aso. Figure 4.4 represents the contents of six options.

After the change of the government, the new Prime Minister, Mr. Y. Hatoyama, announced the 25 % reduction compared to 1990 at the United Nations Climate

Change Summit held in New York in 2009. In reaction to this new mitigation target, the road maps to achieve this 25 % reduction target were quantified at the Central Environment Council. But just after they completed the road maps to achieve the target, the Great East Japan Earthquake and the accident of Fukushima Daiichi Nuclear Power Plant of Tokyo Electric Power Company (TEPCO) happened on March 11, 2011. Due to the nuclear power accident, the GHG mitigation road map and the future energy mix should be reconsidered, because those at that time relied on nuclear power. In 2012, the Energy and Environment Council forecasted that the GHG emissions in 2020 would be 5–9 % reduction compared to 1990 level in the case of the prudent economic growth case.

After the next change of the government, the new GHG mitigation target was officially revised to be 3.8 % reduction compared to the 2005 level under the assumption of the no nuclear power at the COP19 of UNFCCC in Warszawa in 2013. But this target is equivalent to +3.1 % to the 1990 level. At that time, assessment using models was not implemented. Figure 4.5 shows the GHG emission forecasts in 2020 for the high economic growth case by using the AIM/Enduse [Japan] model executed in 2012. In this figure, the target of 2013 is represented by the red line. And Fig. 4.6 shows the relationship between the additional investment cost and saved energy costs. From this figure, the total saved energy costs for the lifetime of each equipment can exceed the total additional investment costs to install the energy-saving equipment. That is to say, if we have long-term perspectives, the energy-saving investment will bring the benefit to the economy in Japan. But in the actual world, the investment is decided from the short-term scope, and then, the introduction of the energy-saving technologies is difficult.

Table 4.2 summarizes the brief history of decision of GHG emission mitigation in Japan and the world.



Share of nuclear power is set to be gradually shifted to the numbers in this figure between 2010 and 2030. "0%" is assumed to be 0% in 2020 and after

Fig. 4.5 GHG emissions in 2020 under the high economic growth case (as of June 2012)

Investment options to reduce GHG emissions

Industry	Energy intensive industries
	Industrial furnace, boiler, etc
Residential	High insulation house
	High efficient & solar water heater
	High efficient appliances & HEMS
Commercial	Energy efficient building
	High efficient & solar water heater
	High efficient appliances
Transportation	Next generation vehicles
	Low fuel consumption
Energy	PV
	Wind power
	Small scale hydro & geo-thermal
	Biomass power
	power system stabilization
	Gas pipelines
	CCS
Others (Non-Energy)	Agriculture
	Waste
	F-gas

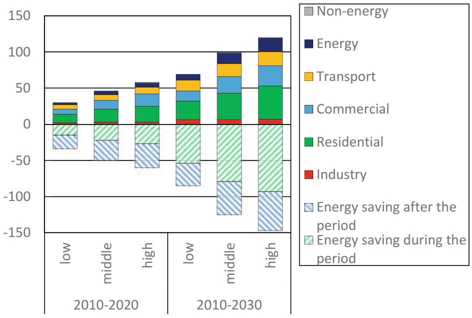


Fig. 4.6 Necessary additional energy-saving investment and saved energy costs (as of June 2012)

4.3 2 °C Target and Mitigation in Japan in 2050

As shown in Fig. 4.1 from IPCC (2014), in order to achieve the 2 °C target, the global GHG emissions in 2050 would be 41–72 % compared to the 2010 level. Since the G8 Summit at Heiligendamm in 2007, the global leaders have shared the long-term vision that the GHG emissions in 2050 should be half compared to the present level. If GHG emission per capita is equal among the world in 2050, it becomes around 2 tCO_2. In the case of Japan, the present emission level is around 10 tCO_2. That is to say, the GHG emissions per capita should be 80 % reduction to achieve the 2 °C target.

In the 4th Environmental Basic Plan endorsed by the Cabinet in 2012, the long-term GHG emission mitigation target was made clear. The target in 2050 is 80 % reduction of GHG emissions. In the following sections, the possibility of 80 % reduction of GHG emissions is examined. The quantitative results are based on Kainuma et al. (2014) for the report of the Deep Decarbonization Pathways Project (DDPP). DDPP is organized by the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), and 15 countries including Japan and international organizations join this project. The interim report was opened at the Climate Summit in 2014. For more information, please see IDDRI and SDSN (2014).

Table 4.2 History of GHG emission mitigation in Japan and the world

Time	Japan	World
May 1992		Adoption of UNFCCC
December 1997	COP3 in Kyoto. Adoption of Kyoto Protocol	
	During 1st commitment period (2008–2012), 6 % reduction compared with those in base year	
May 24, 2007	Invitation to “Cool Earth 50” by then Prime Minister Abe	
	Halving global GHG by 2050 compared with present level	
June 8, 2007		G8 Summit at Heiligendamm: “we will consider seriously the decisions . . . which include at least a halving of global emissions by 2050”
November 2008–April 2009	Discussion of GHG mitigation target at Mid-term Target Committee, Cabinet Secretariat	
June 11, 2009	Then Prime Minister Aso announced GHG emission reduction target in 2020	
	15 % reduction of domestic emission compared to 2005 level	
September 2009	Address by then Prime Minister Hatoyama at the 64th session of the general assembly of the UN	
	GHG emissions in 2020 will be reduced by 25 % compared to the 1990 level under fair and effective international framework	
October - December 2009	Discussion at task force meeting on climate change	
December 2009–March 2010	Discussion at the Investigative Commission on mid-/long-term road map to combat climate change: How to realize 25 % reduction by reconsidering assumptions and countermeasures	
January 2010	Based on “Copenhagen Accord,” each country submitted mitigation target/action plan	
	25 % reduction, which is premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets	
April 2010–March 2011	Results from subcommittee on mid-/long-term road map, the Central Environment Council showed the society in Japan achieving 25 % GHG reduction in 2020 compared to 1990	
November - December 2010		Cancun Agreements at COP16: “Establish clear goals and a timely schedule for reducing GHG emissions over time to keep the global average temperature rise below two degrees”

(continued)

Table 4.2 (continued)

Time	Japan	World
2011.3.11	Great East Japan Earthquake and TEPCO Fukushima Daiichi Nuclear Power Plant accident	
July 2011-June 2012	Discussion at subcommittee on counter-measures/policies post 2013, Central Environment Council	
April 4 2012	The 4th Environmental Basic Plan	
	GHG emissions in 2050 will be reduced by 80 %	
September 2012	Options for energy and the environment by the Energy and Environment Council	
	In the low economic growth case, GHG emissions in 2020 will be reduced by 5–9 % compared to 1990 level. In the high economic growth case, 2–5 % reduction	
	GHG emissions in 2030 will be reduced by about 20 % compared to 1990 level	
	GHG emissions in 2050 will be reduced by 80 %	
November 2013	Then Environment Minister Ishihara announced the new emission target in Japan at COP19	
	3.8 % reduction in 2020 compared to the 2005 level	
March 2015	Deadline to submit the post-2020 target (INDC) by country	
April 30 2015	Government of Japan presented the proposal of GHG mitigation in 2030	
December 2015	COP21 in Paris. The post-2020 target will be decided?	

4.4 How to Achieve 80 % Reduction Target in Japan

As shown in the explanation of the 4th Environmental Basic Plan, the mitigation target in 2050 is set to be 80 % reduction. In order to assess the 2050 target, we utilized the AIM/Enduse to disaggregate Japan into 10 regions. The treated technologies are the same as the analyses for 2020 and 2030 using the national model, and the treatment of future is also the same, that is to say, recursive dynamics. On the other hand, the features of this model are that the local renewable energy potential can be reflected, interconnected line of electricity among the regions can be assessed, and so on.

Other important assumptions are nuclear power and carbon capture and storage (CCS). As regards the nuclear power, the following are the main assumptions:

- Lifetime is limited to 40 years for plants built in 1990 and 50 years for all other plants, and from 2013 to 2035, an additional three GW nuclear plants capacity is included based on the premises of New Policies Scenario of the World Energy Outlook 2013 (IEA 2013).
- Subject to these assumptions and maximum capacity factor of 70 % for all plants, electricity generation from nuclear plants represents about 50 TWh in 2050.

As for the CCS, the following assumptions are set:

- Geologic carbon storage potential.
- Complying with previous studies, CCS technologies are assumed to be available in 2025, and annual CO_2 storage volume is assumed to increase up to 200 $MtCO_2$/year in 2050.

In the illustrative scenario, the primary energy supply and demand in 2050 decreases to almost half compared to the 2010 level as shown in Fig. 4.7. In 2050, renewables and fossil fuels with CCS account for more than 50 % of primary energy supply. In the power sector, the nuclear power is assumed to be phased out gradually, and electricity generation from coal without CCS is entirely phased out by 2050. Renewable energy is developed over the mid- to long terms and reaches approximately 59 % of total electricity generation through large-scale deployments of solar PV and wind power. In addition, natural gas (equipped with CCS) is developed to ensure balancing of the network and reaches about a third of total electricity generation in 2050. Carbon intensity of electricity falls to nearly zero in 2050 as shown in Fig. 4.8. And also, in the final energy demand sector, the energy intensity will be improved, and electricity will be the dominant energy over the long term. As a result, the long-term GHG emission reduction target in 2050 will be reached as shown in Fig. 4.9.

The alternative pathways are also investigated using the same model. In the "without nuclear power scenario," an 80 % emission reduction in 2050 is still feasible. However, higher carbon intensity is experienced during the transition period. The impact of nuclear phaseout as compared to the illustrative scenario is

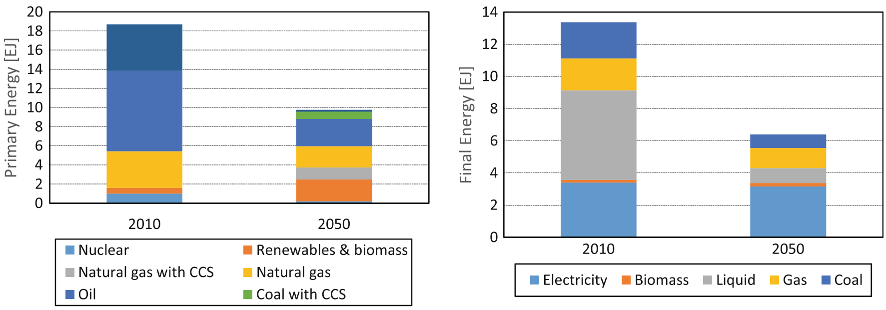


Fig. 4.7 Energy pathways by source

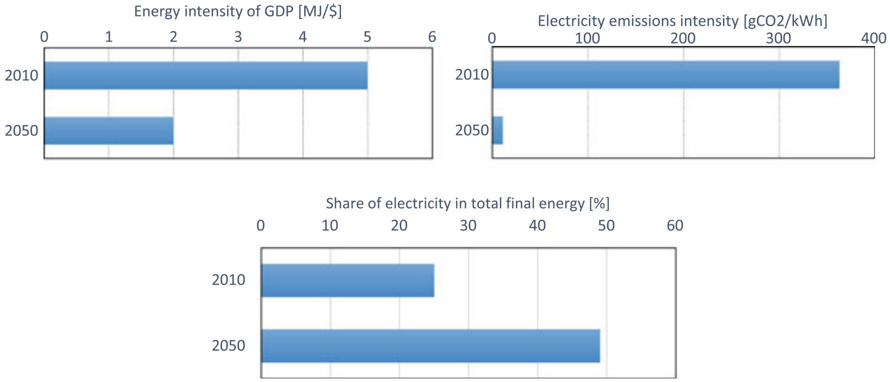


Fig. 4.8 Drivers of decarbonization

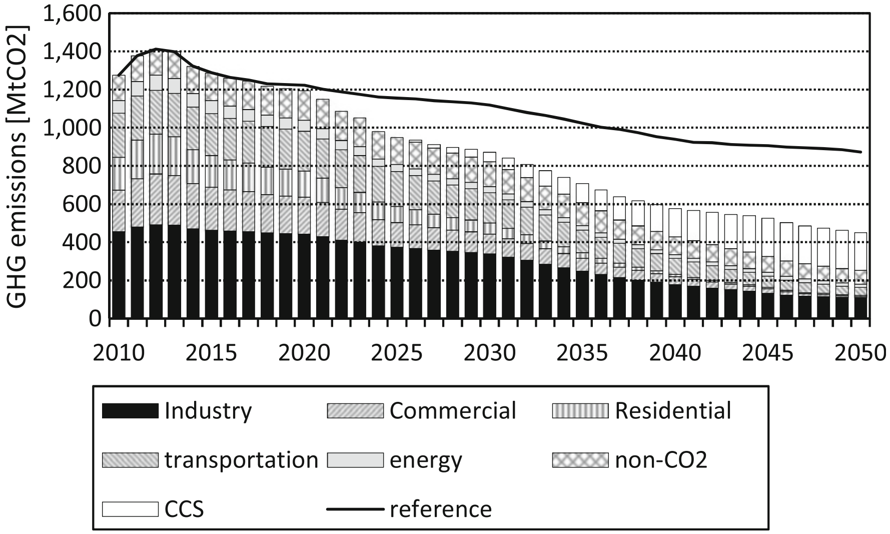


Fig. 4.9 CO2 emission of illustrative scenario from 2010 to 2050

relatively small in the long term, given the small share of nuclear energy in 2050 in any case. Another alternative scenario is “less CCS scenario,” in which CO_2 storage volume is assumed to be limited to 100 $MtCO_2$/year. Achieving long-term emission reduction target proves to be still feasible with substantial increase of renewable energy, particularly solar PV and wind power. The share of renewable energy in electricity supply reaches approximately 85 % in 2050, and variable renewable energies account for about 63 % in electricity generation in 2050, hence imposing a further challenge for integration into the electricity system.

4.5 Conclusion

In this chapter, the historical change of the emission reduction target in Japan and the possibility of 80 % reduction in 2050 in Japan are represented. The feature of mitigation target in Japan is mainly based on the bottom-up approach. That is to say, the process stressed the feasibility of the target. On the other hand, the top-down decision is also requested for the ambitious reduction target.

From the previous estimations, even in Japan, there are still many reduction potentials. Toward the achievement of 2 °C target, taking actions with the long-term perspective becomes more important.

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Chapter 5
Potential of Low-Carbon Development in Vietnam, from Practices to Legal Framework

Nguyen Tung Lam

Abstract Vietnam is not in the category of mandatory reductions of greenhouse gas emissions. However, when implementing the mitigation of greenhouse gas (GHG) emissions, Vietnam has many opportunities to access financial resources, technology and capacity building from developed countries to develop in a sustainable manner toward a green economy with low carbon and contribute to efforts to reduce global GHG emissions. Vietnam should prioritize the sectors for GHG reduction while ensuring the objectives of economic growth, employment, and economic development.

The GHG emissions in the energy and agriculture, forestry and land use (AFOLU) sectors are two of the greatest GHG emissions. Policies to reduce GHG emissions also have negative and unintended effects. Therefore analysis and evaluation of the externalities of policies and measures to reduce GHG emissions are essential. The negative externalities are considered as indirect costs of GHG emission reduction measures, therefore they are important when considering the priority of GHG emission reduction.

International experience of accessing low-carbon development programs from low-carbon development research is a valuable reference for Vietnam. The Asia Pacific Integrated Model (AIM model) to project GHG emission scenarios helps to identify priority sectors that have high potential in reducing GHG and less effects on the development targets. Accordingly, for developing countries like Vietnam, when the budget is not abundant and also to serve multiple objectives of other urgent development, GHG emission reductions in selected priority sectors and actionable measures need less investment and other negative impacts on socio-economic development targets.

Research has contributed to the development of GHG emission reduction policies in Vietnam. It is considered as an important basis for construction, adjustment, and additional amendment of the legal system, mechanisms and policies to promote GHG emission reduction activities in industry and other sectors.

N.T. Lam (✉)
Institute of Strategy, Policy on Natural Resources and Environment, Ministry of Natural Resources and Environment, Vietnam, 479 Hoang Quoc Viet, Hanoi, Cau Giay, Vietnam
e-mail: ntlam@isponre.gov.vn

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Keywords Vietnam • Low-carbon development • AIM model • GHG emission reduction • Mitigation

Key Message to Policy Makers

- In Vietnam, priority sectors should be identified to reduce investment for GHG reduction.
- Great potential exists in the energy, waste and AFOLU sectors in Vietnam.
- Both positive and negative effects of GHG emission reduction policies are identified.

5.1 Introduction

Low-carbon development considers reducing greenhouse gas emissions through reduced energy consumption by technological innovation and social attitudes. Some sectors have great potential to reduce carbon emissions such as energy, agriculture, industries, construction, and waste management. Recent research has shown that Vietnam has great potential to reduce GHG emissions in the energy sector or agriculture. However, to implement a low-carbon development strategy requires large financial capacity, high-tech capabilities and appropriate supporting policies. Besides, improper awareness about the benefits of implementing a low-carbon development strategy, for example, like expensive investment but no immediate economic returns, would be a challenge to successful low-carbon development implementation in Vietnam.

As a developing country, Vietnam has no obligation to reduce emissions in the present, but with implementation of the action program of voluntary reductions of GHG emissions, Vietnam has many opportunities to receive support from other developed countries to develop its economies toward low carbon, and also has an opportunity to contribute to global GHG emission reduction efforts. In a developing country like Vietnam, a policy to develop low carbon will benefit all aspects: reducing energy consumption, increasing energy efficiency, saving natural resources, technological modernization, increased levels of economic value added, and elimination of environmental pollution. This is an opportunity that Vietnam can take advantage of in the future.

Recognizing the importance of implementation of practical actions to respond to climate change, the Government of Vietnam has issued many related legal documents. From 2006 to 2010, the Government of Vietnam adopted many important policies such as the National Strategy for Environmental Protection, the National Target Program for Energy Saving and Efficiency, the National Target Program to Respond to Climate Change, the National Strategy for Solid Waste Management, the National Green Growth Strategy, etc., and promoted the economy toward low carbon. This is an important legal basis for the implementation of sustainable development policy in practice, toward a low-carbon economy in Vietnam. However, to effectively implement the policy, it requires the coordination and cooperation of many agencies and departments from the central to local levels. In particular, the successful experience throughout the world has demonstrated that policy measures toward strategic development of low carbon will provide practical effects if they are confirmed in terms of technology, trade, and economics; socially accepted; and put into a legal framework for implementation.

To be able to implement development toward low carbon effectively, it should be determined what areas of the economy will play a key role in cutting emissions, the level of reductions, and a roadmap of implementation reduction measures in selected economic sectors. The formulation and promulgation of a low-carbon development policy should also consider their potential impacts on the economy such as creating jobs, changes in national income, changing industry structure, economic scale investment requirements and necessary resources to carry out measures for each respective sector. In some countries around the world, especially in developed countries that have committed to the reduction of GHG emissions, growth toward low-carbon emissions is considered as an integral part of a national strategy on climate change.[1] Thus quantitative research on low-carbon development arises as an essential need to provide a scientific basis for management decisions about the goals, schedule and reasonable solutions for strategic planning for economic development in the direction of decreasing GHG emissions. Recently, low-carbon development has received the attention of developing countries where the demand for fossil fuel has been increasing to meet the economic growth in the context of energy efficiency, which is still low. The study of low-carbon development has begun to be deployed in a number of countries with adjustments to suit their socio-economic conditions.

Although still relatively new in Vietnam, the recent problems of low-carbon development have received increasing attention of governments, international donors and agencies. In the implementation process of responsibility to participate in international exchange on climate change, the Ministry of Natural Resources and Environment has proposed to the Government policies and strategies for promoting low-carbon growth and a roadmap to reduce GHG emissions in Vietnam. The Prime Minister approved the National Green Growth Strategy, in which the economic development model toward low-carbon emissions is mentioned as important content of the strategy.[2]

In countries with emission reduction obligations, their policy will be anchored at the cutting rate that was committed to. Thus the trade-off between economic growth targets and the level of GHG emission reduction makes the cutting costs in

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[1] *Low-Emission Development Strategies (LEDS), Technical, Institutional and Policy Lessons. Clapp et al. OECD (2010). Available at* http://www.oecd-ilibrary.org/environment/low-emission-development-strategies-leds_5k451mzrnt37-en?crawler=true

[2] *Decision 1393/QĐ-TTg dated 25/09/2012. "Chiến lược Tăng trưởng xanh quốc gia" (2012, in Vietnamese). Available at:* http://vanban.chinhphu.vn/portal/page/portal/chinhphu/hethongvanban?_page=1&class_id=2&document_id=163886&mode=detail

developed countries very high. For Vietnam, the reduction of GHG emissions should be voluntary so it may optionally give GHG reduction targets. Thus the problem for Vietnam is not how great the trade-offs are but which reduction plans would be preferred alternatives. Identification of the objectives, contents and methods in each sector's cuts and the transformation roadmap to achieve the level of emission reductions cannot follow idealistic sentiments; they must be based on scientific methods of calculation taking into account the specific conditions of the national economic potential of the country, the context of international relations and the requirements of meeting the government's socio-economic development targets.

This paper presents an overview of the recent situation of GHG emissions in Vietnam, as well as a discussion on how the country should select priorities in selecting emission alternatives. It has four main parts; the first one introduces the context of socio-economic development in which GHG emission reduction has been considered as a commitment of the government to the international community for its contribution to the global GHG reduction efforts. The second part presents in detail the main GHG emissions from different sectors and their projections in the years to come. The next part looks at the priority in selecting the alternatives for GHG emissions that are required to help the country to be balanced with its socio-economic development targets. The final part focuses on the impacts of these reduction policies on the country's development with suggestions to reduce unintended effects.

5.2 GHG Emissions in Vietnam

5.2.1 The Total Amount and Level of Greenhouse Gas Emissions in Vietnam

Vietnam signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and ratified this Convention in 1994. Vietnam also signed the Kyoto Protocol (KP) in 1998 and officially approved it in 2002. Under the Kyoto Protocol, Vietnam is not in the group of countries that have a responsibility to reduce greenhouse gases.

Regarding actual GHG emissions, Vietnam is a country with low GHG emissions in the world. The emissions in 2000 were only about 150 million tons, out of 34,000 million tons of CO_2 equivalent emissions worldwide (that is equivalent to approximately 0.44 %). However, it should be recognized that the emission rate per capita in Vietnam, although lower than those in China, Korea and Thailand, is growing faster than the rates in those nations. Specifically, emissions have increased by nearly 6 times, from 0.3 tons CO_2/person in 1990 to 1.71 tons CO_2/person in 2010, while China's emissions increased by 3 times, Korea's increased by 2.5 times and Thailand's increased by 2 times (Figs. 5.1 and 5.2).

Fig. 5.1 GHG emissions per capita during the period of 1990–2010 (Source: Compiled from UN data at http://data.un.org/Data.aspx?d=MDG&f=seriesRowID:751)

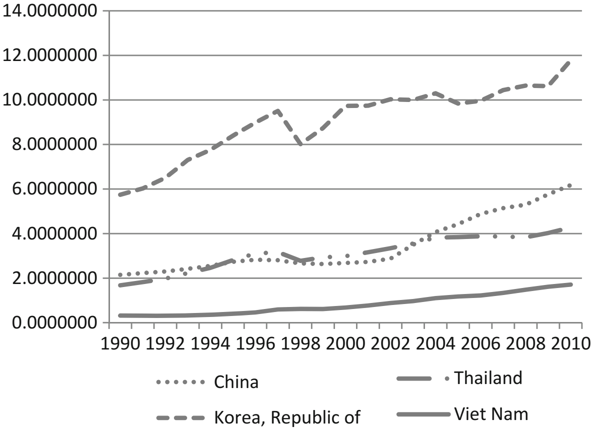
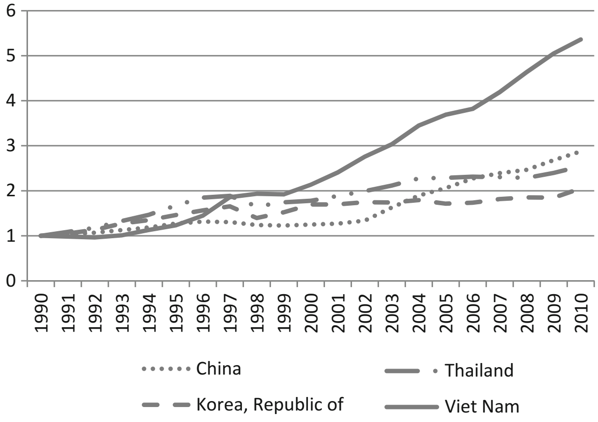


Fig. 5.2 The growing rate of GHG emissions per capita in Vietnam compared with some other countries (Source: http://data.un.org/Data.aspx?d=MDG&f=seriesRowID:751)



In the recent period (2001–2011), before the trend of economic development with a relatively high rate (average growth of 6–8 %), the increase in population led to the amount of Vietnam's greenhouse gases increasing. As expected, due to the economic development needs in the coming years, the amount of GHG emissions in Vietnam may be increased if there is not timely implementation of measures to reduce GHG emissions caused by economic development activities.

Vietnam conducted national GHG inventories for the years 1994, 2000 and 2005. This was to meet the country's commitments under the UNFCCC, also aiming to develop a database to support the formulation of policies related to climate change and greenhouse gases. The inventories therefore covered most sectors' GHG emissions in Vietnam.

All inventories were calculated using the Intergovernmental Panel on Climate Change (IPCC)'s 1996 guidelines for non-Annex I nations (Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories). The inventories for 2000 and

Table 5.1 GHG inventories in Vietnam

Year	1994[a]		2000[b]		2005[c]	
Sector	CO_2 t/đ	%	CO_2 t/đ	%	CO_2 t/đ	%
Energy	25,637.09	24.7	52,773.46	35.0	101,934.90	56.0
Industries	3,807.19	3.7	10,005.72	6.6	14,590.82	8.0
AFOLU						
Agriculture	52,450.00	50.5	65,090.65	43.1	83,828.40	46.1
LULUCF	19,380.00	18.7	15,104.72	10.0	−27,020	−14.8
Waste	2,565.02	2.4	7,925.18	5.3	8,643.41	4.7
Total	**103,839.30**	**100.0**	**150,899.73**	**100.0**	**181,977.53**	**100.0**

Source: Compiled from Vietnam Second Communication Report, Ministry of Natural Resources and Environment (2010), and Interim Report of Inventory Capacity Building Project. JICA (2014)

[a] Second Communication Report, MONRE 2010

[b] Second Communication Report, MONRE 2010

[c] Interim Report of Inventory Capacity Building Project. JICA (as of 6/2014)

2005 were combined with the Good Practice Guidance versions from the IPCC for 2000 and 2003 in a number of areas.

The GHG inventory was conducted in economic sectors that have high emissions, including energy, industrial processes, agriculture, and land use–land use change–forestry (LULUCF), and waste sectors. GHG inventories cover three major categories including CO_2, CH_4 and N_2O.

5.2.2 Structure and Trends in Greenhouse Gas Emissions in Vietnam

A summary of the national GHG inventories in 1994, 2000 and 2005 is given in Table 5.1. The data in the table are the total amounts of GHG emissions in the base year and are converted into CO_2 equivalents. Figure 5.3 shows the trends in GHG emissions from different sectors in the inventory periods.

Excluding the absorption from LULUCF, the volumes of GHG emissions from activities in the industrial, energy, agriculture and waste management sectors also tended to increase, but by different amounts. Among those, emissions from the energy sector have been the fastest rising trend. The change in the structure of GHG emissions as a result of the third inventory excluding the LULUCF sector is represented and trends are shown in Fig. 5.4.

5.2.3 Trends in Emissions from Different Sectors

Emissions from industrial processes and waste account for a small proportion of GHG emissions in Vietnam. With the economic development trend toward green

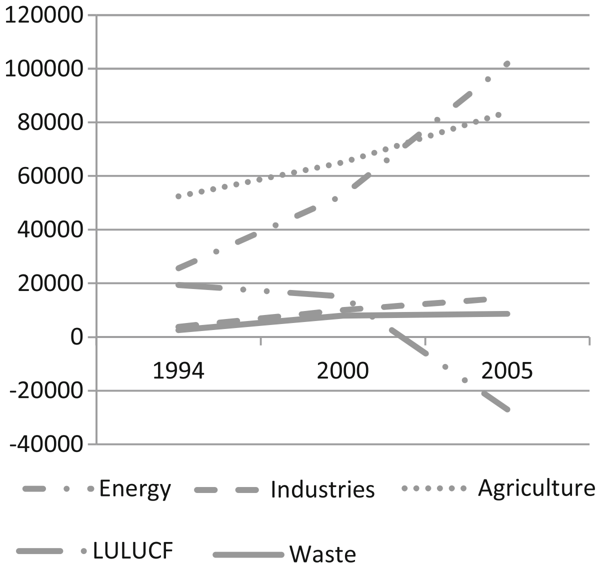


Fig. 5.3 Total GHG emissions from different sectors in the inventory periods (×1000 tCO_2e) (Source: Compiled from Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

growth and low-carbon development, the industries that have high potential for emissions, such as cement, steel, and chemicals, will not likely be developed at high speed to create a larger proportion of the total emissions, while emissions from the waste sector will remain at the same level. Urban development will require accompanied waste minimization and management solutions will reduce the environmental pollution and GHG emissions.

The sectors that currently have the largest proportion of emissions are agriculture and energy. However, emissions from energy will tend to increase rapidly in the coming years in terms of total volume (Fig. 5.3) as well as the proportion of the emission structure (Fig. 5.4). As is likely in most other countries, the energy sector will account for the largest emissions in the economic structure of the country in the years to come.

In the previous year, emissions from the agricultural sector accounted for over 50 % of the components of Vietnam's GHG emissions and emissions of CO_2 and CH_4 (mainly from the energy sector) accounted for approximately 50 %. However, the trend in emissions from energy will increase and serve as the main source of emissions in Vietnam in the coming years, and CO_2 will be the main GHG emissions in Vietnam, beyond emissions of CH_4 from agriculture and waste.

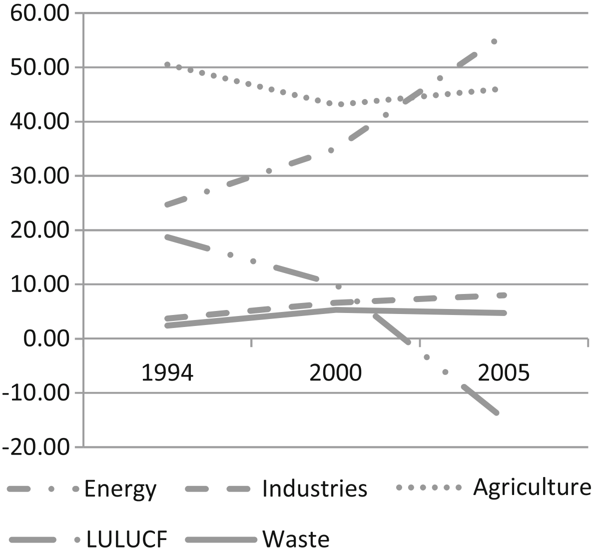


Fig. 5.4 Trends in the proportions of GHG emissions from different sectors (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

5.2.4 Greenhouse Gas Emissions from Different Sectors

5.2.4.1 The Energy Sector

The energy sector has had important implications for the process of sustainable development of the national economy and people's lives in recent years. Vietnam's energy sector has contributed significantly to the country's development, industrial growth and exports. The total primary energy consumption of Vietnam for the period of 2000–2009 showed an average increase of 6.54 %/year and reached 57 million toes (tons of oil equivalents). In 2009, the average coal consumption increased 12.12 %/year, fuel 8.74 %/year, gas 22.53 %/year, and power 14.33 %/year, reaching 74.23 billion kWh.

The total final energy consumption in 2000 was 26.28 million toes, which increased to 40.75 million toes in 2007, during which the proportion of coal consumption increased from 12.3 to 14.9 %, gasoline consumption increased from 26.3 to 34.4 %, gas consumption increased from 0.1 to 1.3 % and electricity consumption increased from 7 to 12.9 %. Regarding the structure of energy consumption by different sectors, this has changed; in 2000, 30.6 % of energy consumption was in industry, 14.7 % was in transport, 1.5 % was in agriculture, 48.8 % was in the residential sector, and 4.4 % was in commercial services. By 2007, the proportion in industry rose by 34.3 %, agriculture increased by 1.6 %, transportation increased by 21.2 %, the civil sector proportion dropped 39.1 %, and commercial services.[3]

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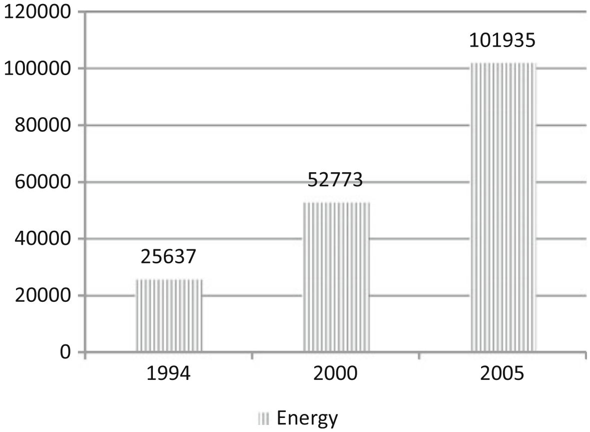
[3] *Vietnam Second Communication Report (*2010*), and Interim Report of Inventory Capacity Building Project. JICA (*2014*).*

Fig. 5.5 Total GHG emissions from the energy sector in the inventory periods (×1000 tCO_2 e) (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)



These figures suggest that in addition to contributing to the country's economic development, the increasing exploitation and use of fossil fuels (coal, oil, gas) for energy have increased GHG emissions. In the energy sector, GHG emissions come from fuel combustion, mining activities and transportation. The main types of emission inventories in the energy sector include (1) GHG emissions from fuel combustion and (2) emissions from GHG emissions. GHG emissions from fuel combustion are divided into sub-sectors: electricity, industry and construction, transportation, trade/services, civil, agriculture/forestry/fisheries, and other. Emissions from GHG emissions are due mainly to coal, oil, gas and gas leaks.

GHG inventory results in the energy sector for the years 1994, 2000 and 2005 are shown in Fig. 5.5.

In total, emissions calculated over the time inventory of GHG emissions from the combustion of fuel account for about 85–90 %, and the rest is due to leakage from the fuel extraction process (coal, oil and gas), storage and transport of fuel.

5.2.4.2 Industrial Processes

The position of industries is increasingly being confirmed in the national economy; the industries are increasingly rich and diverse, ensuring the supply of products and raw materials essential for both consumption and production.[4] Export values of industrial production (in 1994 constant prices) in 2010 were estimated at 795.1 trillion VND, 4.0 times more than in 2000. In the 10 years from 2001 to 2010 the average annual increase was 14.9 %, while the state sector increased 2.1 times, an average annual increase of 7.8 %; the non-state area increased 6.5 times, an average annual increases of 20.5 %; regional foreign investment increased more than 4.7 times, an average annual increase of 16.7 %.

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[4] Ministry of Industry and Trade 2013.

A number of important industrial products for production and consumption have reached a relative high with population growth. The output of coal in 2010 reached 44.0 million tons, 3.8 times the output in 2000, an average annual increase of 13.7 % over the 10 years from 2001 to 2010; 7.9 million tons of rolled steel were produced, a 3.5-fold increase, with an average annual increase of 17.5 %; 55.8 million tons of cement, a 3.8-fold increase, 15.4 %/year; 2.6 million tons of chemical fertilizers, a 2.1-fold increase, 7.8 %/year; 1887.1 thousand tons of paperboard, a 4.6-fold increase, 16.5 %/year; 1.2 billion m^2 of silk, a 3.4-fold increase, up to 13 %/year; 436.3 million boxes of condensed milk, a 1.9-fold increase, 6.7 %/year; 2.4 billion liters of beer, a 3.1-fold increase, 11.8 %/year; and 91.6 billion kwh of electricity were generated, a 3.4-fold increase, 13.1 %/year.

In addition to these results, the development of industries has exposed many shortcomings: low added value and a downward trend, with investment inefficiency and low technology levels.

GHG emissions from industrial processes are not the form of emissions related to energy use in the industrial processes. The emissions considered are those generated by the interaction of the physics and the chemistry of the material during material processing. Heavy and chemical industries in Vietnam so far are only at modest levels, so their GHG emissions are only considered as secondary sources. This is also consistent with the general trend throughout the world.

The GHG inventory for the period between 2000 and 2005 estimated emissions for different types of manufacturing industry, including cement, lime production, ammonium production, carbide production, and iron and steel production. In the first GHG inventory for 1994, the emissions also included the production of paper, alcohol and processed foods. However, the proportion of emissions from these activities is very small, so they are not included in the latter GHG inventories.

GHG inventory results for industry are shown in Fig. 5.6.

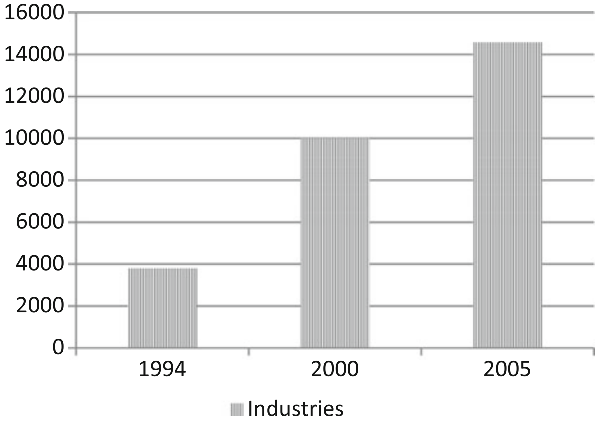

Fig. 5.6 Total GHG emissions in industrial processes in the inventory periods (×1000 tCO_2 e) (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

5.2.4.3 The AFOLU Sector

Agriculture

The agricultural sector in the period of 2001–2010 saw steady growth, providing products with improved quality to better meet the needs of production, domestic consumption and export. The value of agriculture, forestry and fisheries (in 1994 constant prices) in 2010 was estimated at 232.7 trillion VND, up 66.4 % compared with the year 2000. The structures of agriculture, forestry and fisheries have transferred toward reducing the proportions of agriculture and forestry, with fisheries increasing in density. In 2000, the value of agricultural production (at current prices) accounted for 79 % of the total output value of agriculture, forestry and fisheries, and forestry and fishing accounted for 4.7 % and 16.3 %, respectively; by 2010 the proportions were 76.3 %, 2.6 % and 21.1 %, respectively.[5]

In addition to these achievements, the agricultural sector also has some drawbacks such as low-quality products and low value added. Development that has mainly focused on exploiting the potential of land, resources and labor rather than investment in cultivation and processing technologies has led to low-quality products. These inadequacies also lead to negative impacts of agriculture on the environment and ecology, which must be considered in terms of the increasing emissions of greenhouse gases from the types of agricultural activity.

The GHG emissions in agriculture come mainly from activities such as rice farming, raising livestock, emissions from arable land, and burning of agricultural products. The GHG emissions from agricultural activities are CH_4 and N_2O. The agricultural activities considered in calculation of the GHG emission inventory include enteric fermentation, livestock manure management, rice cultivation, agricultural soils, and field burning of agricultural residues. Among the agricultural activities, water rice cultivation account for most GHG emissions (45–60 %), followed by emissions from agricultural soils, enteric fermentation from cattle, and emissions from cattle manure. Other activities make up only a small proportion of emissions. Aggregate emissions from the agricultural sector are presented in Fig. 5.7

According to the 1994 GHG inventory, GHG emissions from the agricultural sector were 52.45 million tonnes of CO_2 equivalents, accounting for 50.50 % of total GHG emissions in the country. By the year 2000 this had changed to 65.09 million tonnes of CO_2 equivalents, accounting for 43.10 % of the total national GHG emissions (including emissions from rice cultivation, which accounted for 57.50 %; 21.85 % came from agricultural soils; 11.88 % came from enteric fermentation, and the rest came from manure management, and field burning of agricultural residues). According to data from the GHG inventory in 2005, GHG emissions from the agricultural sector were 83.828 million tons of CO_2 equivalents, accounting for 46.10 % of total GHG emissions in the country (including emissions

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[5] General Statistic Office (2014).

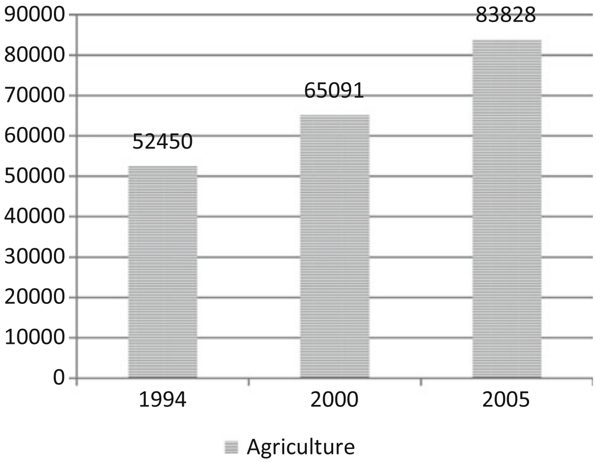

Fig. 5.7 Total GHG emissions from the agriculture sector (×1000 tCO_2 e) (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

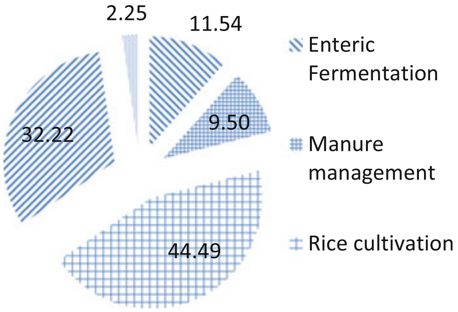

Fig. 5.8 Proportion of GHG emissions from the agriculture sector in 2005 (Source: Interim Report of Inventory Capacity Building Project. JICA 2014)

from rice cultivation, accounting for 44.49 %; 32.22 % came from agricultural soils, 11.54 % came from enteric fermentation, and the rest came from manure management and field burning of agricultural residues) (Fig. 5.8).

Land Use, Land Use Change and Forestry

Forests have roles as both emission sources and GHG sinks. Activities such as land use change and forest exploitation are the source of CO_2 emissions. Meanwhile, the activities of forest protection, reforestation and afforestation are sinks. Forestry, land use and land use change are areas of great potential GHG absorption through the reservoir of carbon from forests, soil, and vegetation if they are well managed, protected and appropriately exploited. The estimation of GHG emissions and absorption in this field focuses on the following main groups of activities: changes in the reserve forest area and biomass in natural forests and plantations; conversion of land use from forest land to other land; abandoned land management; and emission and absorption of CO_2 from the soil. Change of land use often causes

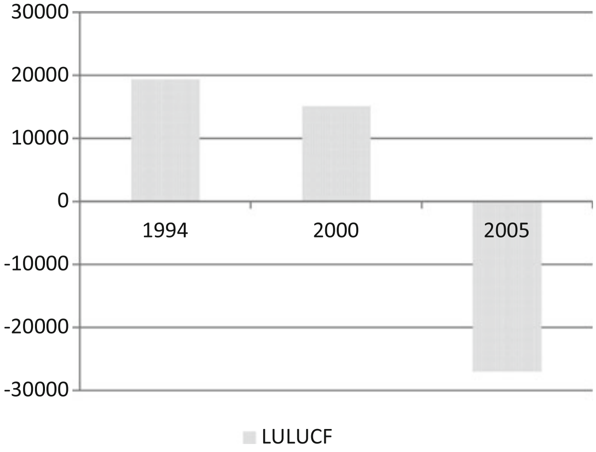

Fig. 5.9 Total GHG emissions from the LULUCF sector (×1000 tCO_2 e) (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

more CO_2 emissions, while change in forest area (in term of increases) often leads to increased levels of CO_2 absorption. The inventory results for this area over the inventory period are given in Fig. 5.9.

According to the 1994 GHG inventory, the amount of GHG emissions in the field of forestry and land use change was 19.38 million tons of CO_2 equivalents, accounting for 18.70 % of total GHG emissions in the country. The GHG inventory in 2000 estimated that the emissions in the forestry and land use change sectors was 15.10 million tons of CO_2 equivalents, accounting for 10 % of the total national GHG emissions. The corresponding figure in the 2005 GHG inventory was −27.02 million tons of CO_2 equivalents, representing −14.8 % of total GHG emissions in the country. Thus, the LULUCF sector has become a major greenhouse gas sink in Vietnam. There is no satisfactory explanation for this sudden change in the calculated results. These issues will also need to be discussed for clarification. But it is clear that the forestry, land use and land use change sector in Vietnam has great potential for GHG absorption through the reservoir of carbon from forests, soil, and vegetation, if they are well managed, protected, and appropriately and sustainably exploited and used.

Waste Management

GHG emissions from the waste management sector are calculated for collected and disposed municipal solid wastes and GHG emissions from domestic sewage and industrial wastewater. It is estimated that every year about 15 million tons of solid waste is discharged from various sources, of which over 80 % are from urban areas, and the rest is industrial waste. However, only part of this waste is collected and processed; the data show that the proportions are over 70 % in urban areas and more than 20 % in rural areas.

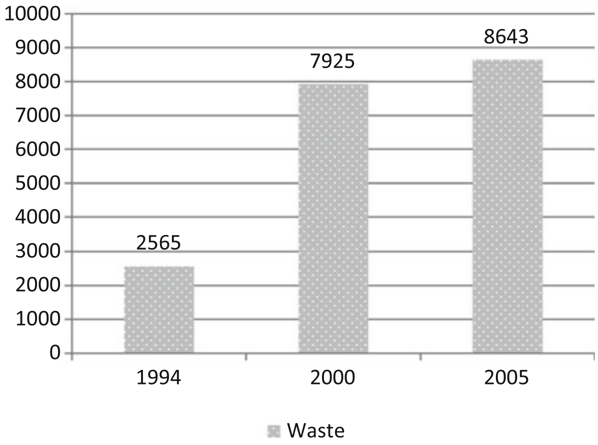

Fig. 5.10 Total GHG emissions from the waste sector (×1000 tCO_2 e) (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

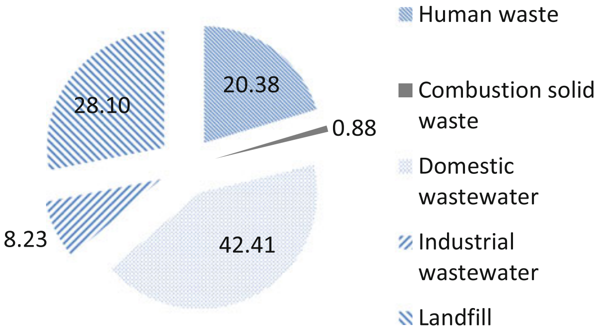

Fig. 5.11 Proportion of GHG emissions from the waste sector in 2005 (Source: Vietnam Second Communication Report 2010, and Interim Report of Inventory Capacity Building Project. JICA 2014)

The calculation of GHG emissions from the waste sector in GHG inventories for Vietnam focuses on the main sources of emissions including CH_4 emissions from solid waste landfills; CH_4 emissions from industrial wastewater and domestic sewage; N_2O emissions from domestic sewage sludge; and CO_2 and N_2O emissions from the incineration of waste. The inventory results are given in Figs. 5.10 and 5.11

In the waste sector, emissions from domestic wastewater are the largest, which are estimated about 3.4 million tons, accounting for about 42 %; the emissions from landfill waste are 2.3 million tons, accounting for 28 %, and the emissions from human waste are approximately 1.69 million tons. Emissions from combustion of solid waste are not high, only about 0.9 % by incineration operations, as this technology is not popular. To reduce GHG emissions from the waste sector requires a focus on the areas of domestic sewage and solid waste landfill.

The data on the status of GHG emissions in Vietnam have shown that two areas that have high levels of emissions are energy and agriculture, while two other sectors, industrial processes and waste, have much lower levels. Depending on the characteristics and properties of GHG emissions in four areas, it shows that to reduce GHG emissions from the energy sector and industrial processes requires large investments with wide impacts on socio-economic aspects; while the potential to reduce GHG emissions from the AFOLU sector and waste management may require lower funding with fewer impacts on the economics. In particular, the LULUCF sector also has high potential for GHG absorption. However, to get a clearer view of the potential to reduce GHG emissions, it is necessary to analyze and assess the opportunities and challenges for reducing GHG emissions in Vietnam.

5.3 Identification of External Impacts of GHG Emission Reduction Policies

5.3.1 Externalities of Greenhouse Gas Emission Policies

In the context of climate change impacts, the debate about the achievements and negative impacts of policies to reduce GHGs is becoming more and more popular. Recently, this problem has attracted a more extensive and more detailed focus on the benefits and costs of the externalities of the policy options and mitigation plans. Basically, these externalities can be understood as policies and plans to reduce greenhouse gases that could, in some way, cause a positive or negative impact on the economy, public health, ecosystems, etc. And, in this case, the effects can be monetized; they should be subtracted or added to the social cost of emission reduction policies. The positive externalities can be created through minimizing damage to the environment and the health of the pollutants. Conversely, these policies can also create negative externalities for public health and the environment, for example, in the field of energy, the increased use of diesel fuel can reduce GHG emissions, but will increase the risks to environmental and human health. Generally, these externalities have not so far been studied and evaluated fully, and so rarely have been quantified in a systematic way and integrated into the emission reduction policies. Failure of consideration and evaluation of the impacts of externalities may affect the choice of policies to reduce emissions. The externality, accordingly, should be considered as one of the indicators to identify the priorities for policies to reduce GHG.

5.3.2 The Impact of Macroeconomics

Policy impacts on the energy sector such as fossil fuel price rises, or policies imposed on the industrial sector such as rising commodity prices related to GHG emissions, can help reduce emissions as well as the risks of climate change in the long term; conversely, however, they also reduce economic activity in many forms.

Although these effects on the economy's growth may not be large in the long term, they need to be considered. The policies on reducing GHG emissions that impact on economic activities can be generalized as follows:

- The shift in production, investment and labor from industries related to energy production based on carbon, or products and services that use a lot of energy, to industries using alternative energy sources and consuming less energy;
- Reduced productivity of capital and labor in accordance with the cheap energy available;
- Reduced household incomes, with a reduction in domestic reserves;
- Lack of encouragement for investment due to increasing capital costs of production processes using a lot of energy;
- Reduced amount of net income from abroad (decreased productivity and increased cost of production capital), making the domestic market become less attractive to foreign investors;
- Deterioration of total labor supplies due to increases in the cost of consumer goods and reductions in the real wages of workers.

The GHG emission reduction policies may affect GDP growth through investment mechanisms. For example, high taxes on production that has a high level of GHG emissions will cause increases in production costs, thereby reducing investment and leading to a decline in product supplies and real wages. Accordingly, the consumption by people will fall and, as a result, reduce GDP. At the same time, lower wages can reduce workers' choices for employment that is unpaid or is not reflected in GDP, such as parenting, employment at home or entertaining.

5.3.3 The Problems of Hunger Eradication and Poverty Reduction

Solutions to reduce GHG emissions can cause a significant impact on the goal of social economic development—typically the impact of policies to reduce emissions in AFOLU on food security. The current efforts in reducing poverty, curbing malnutrition and improving incomes are oriented toward increasing the rate of food production per capita in developing countries, while population growth will require increases in income. Therefore, a policy of increasing food production is needed to ensure sustainable development of the country. Accordingly, solutions to reduce emissions from the AFOLU sector if contributing to food production will contribute positively to this work. In contrast, there will be a number of solutions that may reduce food productivity, at least at the local scale.

In the energy sector, energy scarcity has prompted developed countries to seek biofuel sources, displacing food production in agriculture. This has caused serious food shortages. These factors push up food prices, making the supply drop, and poor countries suffer the most severe consequences.

5.3.4 The Impact on Employment

In the case of policy applied to goods prices based on the corresponding GHG emissions created during their production and consumption, these policies may affect the total supply as well as the distribution of employment between sectors of the economy. For example, the commercialization of emissions to manage emissions from the energy sector of the USA has only generated a small amount of change in total employment over the long term, but the changes created by this policy have partly impacted on employees. Specifically, rising energy prices reduce the real wages of workers. Meanwhile, some people may choose to work fewer hours, or even stop working to switch to operating in other areas.

Although there is no major impact in the long term, the GHG emission reduction policies can cause a significant shift in the structure of labor between sectors of the economy. For example, the commercialization of emissions from the energy sector in the USA could reduce the number of carbon- and energy-intensive industries in energy production or manufacturing of products consuming energy due to these industries facing the problems of increased production costs and reduced outputs. In particular, the energy industry, such as coal mining, oil and gas, may be most severely affected. In addition, emission reduction policies also affect employment in industries that use high-emission products, such as the transportation and chemical industries. In contrast, the policy will create new jobs in other sectors, particularly the manufacturing of machinery to produce energy without CO_2 emissions, such as producing electricity from wind and solar power. Similarly, employment can be increased in sectors producing goods and services using less energy or less energy consumption products, in which the services sector may have the most significant increase.

5.3.5 The Impact on Energy Security

Security of the energy supply side can be defined as “the availability of energy at all times in many forms to ensure sufficient quantity and at an acceptable price” https://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/. This definition refers to the prevention and mitigation of emergencies in the short term as well as limiting the risk of energy security in the long term.

Climate change and energy security have become the two main drivers of energy policy in the future of the country. While energy security has been the focus of energy policy for nearly a century, the concern about climate change has emerged in recent times, but has a significant influence and alters virtually all of the context of energy policy. The key problem that decision makers are faced with is how to simultaneously ensure national energy security, while reducing GHG emissions. There is no guarantee of energy security, often due to the non-availability of energy and because energy prices are not competitive or are too unstable. In fact, these effects are often very difficult to assess; therefore, it is difficult to determine a reasonable policy. In the context of climate change, countries usually have a certain number of activities to ensure energy security. Firstly, countries may seek to minimize the short-term effects due to lack of power supply in case of power interruption or, secondly, may make efforts to improve energy security in the long term. In the first case, the country often resolves to build strategic reserves. For example, in the case of oil, the International Energy Agency (IEA) coordinates the use of emergency oil reserves between member states. The government also seeks to establish contingency plans to limit consumption, thereby minimizing the impact due to the lack of energy. In the second case, the policies tend to focus on determination of the root causes of loss of energy security in the context of climate change, such as interruption of power systems related to catastrophes or extreme weather conditions; balancing supply and demand in the market for short-term power; monitoring the effectiveness of management and regulation; and focusing on fossil fuel sources by minimizing the possibility of the risk of depending on the supply of energy in the traditional market and reducing use of fossil fuels or diversifying the type of power supply.

Each system of energy security policy allows identification of potential overlaps with policies and measures to reduce GHG emissions from the energy sector. For example, policies to address resources can significantly affect GHG emissions and vice versa, because they tend to impact the choice of fuel and related technologies. In contrast, policies to overcome regulatory failures can only have a secondary impact on emission reduction policies. Thus GHG emission reduction policies can cause a great impact on plans and strategies to ensure energy security in the country.

5.3.6 The Impact on the Environment

The GHG emission reduction policies may also impact the environment. For example, in the energy sector, hydropower development can affect the environment and ecosystems at the construction site. In the AFOLU sector, emission reduction policies often affect land availability and competition, while land developers may have different perspectives on the importance of ecosystem services. Policies to increase food production may reduce environmental services. Policies to reduce GHG emissions from the agricultural sector often have positive impacts as can be seen in countries that have suffered from declines in water quality and ecology, and sedimentation. These losses can be reduced by implementing conservation tillage measures that will provide benefits in terms of land recovery, or will limit soil erosion. Other positive externalities of GHG reduction policies are changes in farming practices to cause an increase in organic matter in soil, improve the water holding capacity of the soil and reduce the need for irrigation; increased organic matter in the soil can improve soil fertility, which reduces the need to use inorganic fertilizers; conversion from farmland to grassland or forest land can improve the habitat of wildlife and biodiversity protection; restriction of fertilizer use can reduce the nutrient content of the overflow from agricultural land, thereby improving water quality and reducing the shortage of oxygen in rivers, streams, lakes and aquifers. These changes will improve the characteristics of the water used for non-agricultural activities in the area.

However, besides the positive impacts, the greenhouse gas emission reduction policies in the AFOLU sector can also create externalities costs that are not small, as in some cases, reducing the intensity of arable land use requires the use of more pesticides to control weeds, fungi and insects. In addition it requires additional energy for synthesis, production and application. These activities also have negative impacts on the ecosystem, flow and water quality.

5.3.7 Reducing Costs and Losses from Climate Change Impacts

The adoption of policies to reduce GHG emissions help to avoid the risks of climate change. Such risks include reduced potential crop yields in most tropical and subtropical regions due to the increase in temperature; reduced and changed crop yields in most regions at mid-latitudes due to the increase in average annual temperature; reduced water supplies in areas of water scarcity, especially in the subtropics; increases in the number of people exposed to vector-borne diseases (such as malaria) and water-borne diseases (such as cholera) and mortality due to heat stress (heat stress, mortality); increases in the risk of widespread flooding of many residential areas due to increased rainfall and sea level rise; and increased energy demand for cooling due to higher temperatures in the summer. The implementation of GHG reduction policies in these areas will help to avoid the costs or potential losses that are caused by climate change impacts.

5.3.8 The Social Impact

Social costs to operate and monitor the climate change and reduction of GHG emission programs are often not small, and include labor costs, raw materials, project implementation costs, the cost of raising awareness and compliance with emission standards, the energy accounting program, reducing emission labeling, etc. In case the costs are not included in these specific GHG emission reduction measures, they should be regarded as a form of external costs. Normally, the costs of GHG emission reduction activities are often much higher if they are calculated fully.

As the above analysis shows, to reduce GHG emissions from different sectors, in addition to calculating the direct costs for reducing emissions, there is a need to assess carefully the effects of the policy of emission reduction, especially the negative externalities; these are the indirect costs to be paid in reducing GHG emissions. The choices of priorities, plans and measures to reduce GHG emissions in accordance with the actual conditions of each country require consideration and full evaluation of all of the externalities.

5.4 Selection of Priority Areas and Measures to Reduce Emissions of Greenhouse Gases

5.4.1 Selection of Priority Areas

Identifying priority areas for policy implementation should be based on the criteria that the externalities have been taken into account. The implementation costs criterion represents the economic efficiency of emission reduction countermeasures, usually expressed as the monetary value per unit of CO_2 avoided when implementing these measures. The assumption is that the lower the cost is, the more attractive the options are. Conversely, the choices for emission reduction measures have higher costs that will not be a priority in the early stages and can be implemented later.

The priority policies should have the ability to meet the emission reduction targets of the country. This indicator reflects the level of impact and the ability to contribute to GHG reduction targets of selected sector emission reduction measures. It is usually based on the percentage of CO_2 emissions from the sector compared with the total amount of the CO_2 cut off. The sectors that have higher potential emissions will be placed at greater priority.

The applicability of the policies is an important criterion to prioritize the measures. This reflects the necessity for a change in legislation or institutional systems to enable the successfully implementation of emission reduction measures. Typically, measures that require little change or effects on other policies when being implemented are often easier to implement and therefore will prevail.

There are several factors affecting the applicability and implementation of GHG emission reduction measures. If there are many similar implementing measures that have been done before, it will be better with this experience. Reducing the number of decision makers who have a key role in the implementation of measures to reduce emissions in priority areas would help to implement the measures quickly and effectively. The complexity of the preparatory activities will help to shorten the timeframe for implementation. The level of diversity of the groups that the reduction measures will be directed at should be as little as possible. As usual, a greater number of targeted groups will require more work on related policies.

The reduction measures should have the ability to combine with activities to improve the quality of life. This reflects the extent to which the measures will supplement and support policies and other measures aimed at improving the quality of life of people, such as poverty reduction and energy security. To a certain extent, this reflects the priority that reducing emissions will not only limit the amount of CO_2 emissions but also contribute to reducing the burden of negative effects on people's health or the ecosystem.

Preferable measures will help to create job opportunities. This is the social impact of the measures. It is mainly based on indicators of jobs directly created to implement measures in priority areas to reduce emissions.

Another important factor to be considered in determining the priority areas for reducing GHG emissions is that they need to be in compliance with the priorities of the country's development policies. Determining priority areas for GHG emission reduction therefore is weighted in accordance with the development goals of the country. The priorities for development will be essential in determining areas for reducing GHG emissions.

5.4.2 Identifying Technical Solutions—Technology Priorities in Reducing Greenhouse Gas Emissions

After defining the field of emissions and identifying technical solutions, specific technologies to reduce emissions from different sectors also have very important implications for the GHG emission reduction strategy of the country. Usually, technical solutions and technologies are applied to the sector, and sub-sector emission reduction priorities are classified according to their applicability in the short term and long term, or on a large or small scale. The classification results allow comparison with other solutions and building system solutions applied over time. Accordingly, the solution can be applied to many sectors/sub-sectors, though not with the highest priority in all sectors/sub-sectors identified.

5.4.3 Lessons for Vietnam

The identification of priority areas to reduce emissions requires specific research, based on national conditions and the development goals. Accordingly, there is a need to develop criteria to identify areas in which to consider the full range of aspects of the potential to reduce emissions, the ability to deploy, the cost and other economic, social and environmental effects.

For reduction of GHG emissions from the energy sector and the promotion and development of new energy sources, renewable energy often requires great support financially from the government to businesses, including investment costs, installation costs, operating costs and R&D activities. Therefore, for developing countries like Vietnam, the budget must also cater for multiple items for other urgent development, and focusing on investment in the development of renewable energy sources will encounter many difficulties, so there is a need for a strategy and roadmap for this. As an agricultural country, Vietnam has the potential for development of bioenergy from agricultural by-products to partially replace fossil fuels to reduce GHG emissions without too much investment cost.

With the economy still relying heavily on agriculture in the next decade, not only for rice but also for other industrial crops (coffee, tobacco, rubber, pepper, and cashews), Vietnam needs to focus on building sustainable agriculture and application of advanced agricultural technologies to maintain and develop the quality and quantity of agricultural production in the context of climate change. For application of this new technology, besides support from the Government of Vietnam, support from developed countries should be enlisted in parallel with relief efforts. This will ensure appropriate orientation and mitigation of GHG emissions associated with climate change adaptation under the most favorable orientation for Vietnam.

In the forestry sector, the strengthening of forestry on vacant land in the tropics is known as an effective measure to reduce CO_2, the main GHG in the atmosphere. In addition to reforestation efforts and reforestation on barren hills, recently the international community has also shown interest in sustainable management of the available forest resources. REDD+ initiatives have been proposed and have received the attention of many nations. This initiative stems from the fact that deforestation and forest degradation contribute a large proportion (15–20 %) of the total amount of GHG emissions due to human activities, and the cause is global in scope.

The formulation and implementation of policies to reduce GHG emissions need to be considered in a comprehensive manner, which requires close coordination between ministries and departments.

The GHG emission reduction strategies should be implemented in a flexible manner, combining policy commands with incentives and economic and technical support to encourage the cooperation of the relevant parties.

Efforts should be made to encourage participation and promote the role of stakeholders in the GHG emission reduction activities. The involvement of the community and stakeholders not only helps to ensure cooperation with and support of government policies but also can help to sustain the motivation of the Government in working toward GHG emission reduction targets.

Leverage, promoting investment, is an important factor in GHG mitigation and response to climate change, especially in developing countries with limited funds. The collaboration and support between Norway and Brazil in the successful campaign to reduce emissions from deforestation in Brazil have demonstrated the role and importance of external sources of support for activities to reduce emissions.

Application of techniques and technology is one of the essential elements to ensure effective policies and activities to reduce emissions, and in return, such mechanisms and policies are promoting the implementation and application of technical solutions and technologies to reduce GHG emission practices.

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Part II

Bridging the Gap Between Modeling and Real Policy Development