Methodologies for leapfrogging to low carbon and sustainable development in Asia

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I. INTRODUCTION

World leaders agreed at COP21 to reduce greenhouse gas (GHG) emissions due to human activities essentially to zero during the latter half of the 21st century, moving toward the target of limiting the average global temperature increase to no more than 2 °C, and to drive efforts to limit the temperature increase even further to 1.5 °C above pre-industrial levels (UNFCCC, 2015). Another significant development in 2015 is the adoption of the 2030 Agenda for 17 Sustainable Development Goals (SDGs) (UN, 2015). Climate change is one of the most important and urgent issues concerning SDGs, as the current actions greatly influence future environment and human activities. Moreover, many actions toward climate change can also help to achieve other SDGs such as ensuring access to affordable clean energy and to build a resilient infrastructure.

Asia has an important role to play in achieving these goals. The Asian region contributed to approximately 38% of global GHG 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 mitigation efforts are not made. Moreover, early mitigation actions are a necessity in all Asian countries to avoid high carbon lock-in from long-life energy technologies. At the same time, domestic conditions of resource availability and developmental priorities vary among different Asian countries. Therefore, aligning GHG mitigation policies and actions to domestic conditions in each country would be useful to enhance their acceptability and effectiveness.
The low carbon society (LCS) transition by Asian countries will not be an easy task. In order to accomplish the transition, it is vital that stakeholders including central and local governments, private sector enterprises, non-government organizations (NGOs) and non-profit organizations (NPOs), citizens, and the global community tackle it with a focused and common vision of the society they wish to achieve. In addition, careful attention should be given to the diversities of the level of development, resources, climate conditions, and cultures of the Asian countries when it comes to the implementation of countermeasures. However, there are certain common means and requirements for realizing a LCS that could be shared as a guiding framework for all countries.

The Asia-Pacific Integrated Model (AIM) team has been supporting the development of LCS scenarios in Asia through capacity building over twenty years. Many scenarios have been developed in this period. Through repeated calculations and discussion, the necessary levels of implementation and emission reduction by mitigation options have been assessed and a list of potential low-carbon measures has been constructed. From this experience, we have also gained insights into methodologies for preparing LCS roadmaps and procedure to design LCS policies in Asia.

The feasibility of leapfrogging to low carbon and sustainable development in Asia and how the policies are to be formulated are presented in Section II. In Section III, common methodologies that can be used to prepare plans and roadmaps toward a LCS, as well as country specific approaches, are presented. Applications of these methodologies in Asian countries are presented in Section IV. Procedures to design and implement low carbon policies together with the Plan-Do-Check-Act (PDCA) cycle are presented in Section V followed by the Conclusion.

II. POLICY FRAMEWORK FOR LOW CARBON DEVELOPMENT

Before we discuss the process of constructing and implementing LCS roadmaps and actions, it is useful to first describe the framework for the development of low carbon policies. Such a framework includes target setting, policy formulation, monitoring, and feedback.

A. Systematic formulation of low carbon development policies

While it is urgent to realize low carbon and sustainable development in Asia, it is also pertinent to note that Asia has the capacity to do it. The LoCARNet Iskandar Malaysia Declaration, released in 2015 in Malaysia by the Low Carbon Asia Research Network (LoCARNet, 2015), stated that transformation of Asian economies into sustainable low carbon economies by embracing green growth needs to be accelerated, and it could be achieved by leveraging Asian wisdom that espouses “mottainai” (frugality), “gotong-royong” (collective action), a sufficiency economy philosophy, and mutual benefits for all. It further noted that this could be done through inclusive and enabling policies that empower people to take positive climate stabilization actions, by designing policies that are not only based on good scientific evidence but also feasible in terms of implementation. The Declaration called for an emphasis on new opportunities and possibilities for economic growth in Asia arising out of climate change mitigation and adaptation actions.

As energy policy is at the core of GHG emission reduction, it goes without saying that control on energy consumption and a change in the structure of primary energy supply are required. However, policy cannot stop there—transitions are required in all sectors related to consumption and supply, including cities, land use, residential, transport, and industry. The various sectors that must be covered by climate policy are indeed wide-ranging.

Figure 1 shows the structure of policy processes and their supporting elements. Reduction targets are often decided \textit{a priori}, as international agreements of the UNFCCC or as decisions by top leadership or top management (e.g., the 26/41% reductions announced by the former President Yudhoyono of Indonesia). Leading up to these decisions are deliberations on approximate reduction outlooks and setting of rough targets (Ishikawa and Nishioka, 2016).
Based on the low carbon target, climate mitigation policies are carried out following the processes of policy formulation, policy implementation, and policy evaluation. Results of the implementation and evaluation are feedback to refine the policy.

Scenarios are developed to provide a scientific basis for policies. Scenarios offer a structured means of organizing information and gleaning into the possibilities of LCS. LCS scenarios can be developed by using integrated assessment models and data. The Asia-Pacific Integrated Assessment Model (AIM) has been developed focusing on the characteristics of the Asia-Pacific region and has supported policy formulations in Asia (Kainuma et al., 2003 and Masui, 2012).

Implementing mitigation measures suggested in LCS scenarios requires actions and roadmaps supported by LCS policies. LCS policies include interventions mandated by governments, institutions, or other entities and may include laws, directives, and decrees; regulations and standards; taxes, charges, subsidies, and incentives; information instruments; voluntary agreements; implementation of new technologies, processes, or practices; and public or private sector financing and investment, among other mechanisms (Gomi and Matsuoka, 2016).

The Paris Agreement (UNFCCC, 2015) requests the Parties to regularly review the implementation of the Agreement and take necessary decisions to promote its effective implementation. Effective implementation processes require iterative procedures which the PDCA assessment cycle can provide. The PDCA assessment cycle is applied to the whole process in order to ensure systematic and iterative planning, execution, evaluation, and improvement of actions. Results of actions by each stakeholder group are consolidated periodically to undergo MRV (measurement, reporting, and verification), whereby feedback is given on reinforcement of measures and changes to plans. Through PDCA, inventories and integrated assessment models used in the early stages of planning are effectively utilised as tools to assess the efficacy of measures.

LCS policies involve green economy investment and finance and social infrastructure design. They also need a change in consumption patterns and behavior. Implementation of LCS policies requires a participatory process in which persons from various fields collaborate. Monitoring GHG data and evaluating policies are the basis to improve the LCS policies.

B. Planning of leapfrog strategies for low carbon society (LCS) in Asia

Several examples of leapfrog strategies can be found in Asia. For example, REmap analysis by IRENA (2014) shows that China could scale up modern renewables to 26% by 2030.
The required investment of USD 145 billion per year could potentially save China more than USD 200 billion a year by 2030, factoring in the benefits of improved health and lower CO₂ emissions. Iskandar, Malaysia, has integrated the blueprint for climate mitigation in its development agenda. It aims to achieve green economy by focusing on several factors such as information and communication technology, safety and security, and heritage and culture (Iskandar, 2016). Bhutan, a nation of about 750,000 people covered by at least 60% by forest, seeks to balance economic growth and environmental conservation. It has a vision of 100% renewable energy supply based on hydropower as the main source of electricity supply (Kumar, 2014).

The Paris Agreement seeks to achieve a long-term goal to limit the temperature increase well below 2°C and pursues efforts to limit it to 1.5°C above pre-industrial levels by the end of 21st century. At the same time, it requests countries to achieve their nationally determined contributions, the timespan of which is 2025 or 2030 (UNFCCC, 2015).

While several countries have already developed and implemented leapfrog strategies for LCS in Asia, others are still under development. In order to develop leapfrog strategies, strategic objectives need to be considered not only in the short term but also in middle to long terms. A time-phased pathway of strategic objectives, selected generic actions, and policy and governance triggers is outlined in Table I. This has been prepared based on the results of AIM models for countries and cities in Asia, the experience of developing LCS roadmaps together with national and local stakeholders, and the insights gained by the AIM team in the process of

<table>
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<th>Time phase</th>
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<td>Tactical objectives</td>
<td>Set national and sector level goals</td>
<td>Accelerate drastic GHG emissions cuts</td>
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<td></td>
<td>Introduce available low carbon technologies</td>
<td>Begin explicit and accelerated transition to low carbon society</td>
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<td>Build policy and infrastructural platform for transition to low carbon society</td>
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<td>Example of generic actions</td>
<td>Strengthen and implement INDCs</td>
<td>Build physical and social infrastructures and policies to induce drastic change in social structures, behaviour and life-styles</td>
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<td>at national and local levels</td>
<td>Implement sector level policies with domestic goals that align with climate goals</td>
<td>Accelerate explicit and strong low carbon policies and regulations that accelerate diffusion of low carbon technologies and infrastructures</td>
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<td>Introduce educational programs to raise awareness of low carbon society and options;</td>
<td>Re-define national prosperity and progress in terms of a comprehensive set of sustainable development indicators</td>
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<td>Mainstream such education in school and university curricula</td>
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<td>Enhance international collaboration to expedite technology development and transfer</td>
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<td>Policy, regulatory and</td>
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<td>Enhanced intra- and inter-sector budgets directly allocated to low carbon and sustainable development targets</td>
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<td>governance triggers</td>
<td>Cross-sector policy instruments, incentives and regulations</td>
<td>Strengthened democratic and local/decentralized governance processes</td>
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<td>Sector level performance metrics linked to objectives such as energy efficiency, sustainable development, energy security, local environment</td>
<td>New set of performance metrics, based on low carbon, sustainable and holistic socio-economic development, become a norm and drive decisions</td>
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<td>Enhanced sectoral allocation of budgets</td>
<td>Democratic-federal governance processes, with involvement of local citizens/communities</td>
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<td>Initiation of processes of democratic governance and citizens’ participation at national and local levels</td>
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collaborating with researchers in Asian countries. This could be a guideline for elucidating a
detailed roadmap of specific actions, policies, and other preparatory interventions (IPCC AR5,
2014 and Matsuoka, 2015).

Early mitigation actions are a necessity in all Asian countries to avoid high carbon lock-in
from long-life energy technologies. However, at the same time, domestic developmental priori-
ties in individual countries, such as poverty elimination, cutting local pollution, achieving
energy, and water security, are crucial. Therefore, a pragmatic strategy in early periods is to
take actions within overriding domestic and sector level goals of a nation. Thus, GHG mitiga-
tion actions aligned within the agenda of domestic and sector level developmental objectives in
the short run could seamlessly yield integrated, cross-sector and drastic actions within explicit
and mainstreamed LCS agenda in the medium and long run.

III. METHODOLOGIES TO EXPLORE LCS

There is a rich worldwide experience in development of quantitative modeling tools for
assessing LCS and LCS type scenarios. The rigour of modeling methodologies permits compre-
hensive evaluation of consistency, feasibility, and impact of scenarios. In this section, we
briefly discuss some of these methodological frameworks and tools.

A. Low carbon analysis framework

Advanced modeling techniques have been developed to carry out LCS scenario analysis. As the problem of climate change and GHG emissions is deeply rooted in the human and eco-
nomic activities and the use of resources including energy and land use, the LCS modeling
frameworks adopt integrated assessment methodologies that simulate complex interrelationships
among GHG emissions, climate change, and impact domains, as well as multiple variables of
human-economic and energy systems.

Several modeling tools such as Asia-Pacific Integrated Assessment Model (AIM), Long-
range Energy Alternatives Planning Model (LEAP), Market Allocation Model (MARKAL), and
World Induced Technical Change Hybrid Model (WITCH) have been developed by various
research teams and applied to the Asian region, among others, to analyse energy-emissions-
economy interactions in the context of climate change (for instance, see USAID, 2013;
Orecchia, 2015; Raitzer et al., 2015; and Westphal et al., 2013). While all these modeling
applications provide useful insights, AIM is a family of models that together cover a range of
complementary methodologies—top-down and bottom-up, technological and macroeconomic,
regional/national scale, and local/city scale. In contrast, each of the other models covers a sin-
gle major methodology and has been applied to a single region or country. AIM models have
been applied to several regions, countries, and cities in Asia as part of a continuous and long-
term collaborative process among climate change researchers in various Asian countries that
have already spanned over two decades. The authors have been members of the AIM team for
most of this period. For these reasons, we focus here on the methodology and applications of
AIM models.

Figure 2 shows the framework of AIM. Although the AIM model has been developed pri-
marily to help respond to climate change problems, it has been extended and applied to other
related environmental problems such as air pollution, waste management, and water resource
management (Kainuma et al., 2003 and Kainuma and Pandey, 2015). AIM consists of a family
of models with several analytical models, each of which is developed to analyze a specific set
of sectors and policy issues. These models are interlinked in order to provide an integrated sys-
tem for emission-climate-impact/adaptation assessment.

AIM is a tool to provide pathways to a LCS while ensuring consistency among sectors and
policies. It can provide a comprehensive assessment of various policies, including macro-
economic policies and technological measures. It can analyze trade-offs between rapid eco-
nomic growth in Asia and its environmental impact and assess sustainable development
policies.
The integrated system has several core emission models and element models. The core emission models are Computable General Equilibrium (CGE) model, Enduse model, Extended Snapshot (ExSS) tool, and Agriculture, Forestry and other land Use (AFOLU) model. LCS scenarios can be developed by linking these models.

B. A family of models in Asia-pacific integrated assessment model (AIM)

AIM/CGE is a tool for keeping macro-economic consistency among supply, demand, and resource constraints and estimating macro-economic impacts. It can simulate macroeconomic, energy, and technology dynamics under different scenarios. Significant changes in energy systems are required to transform to a LCS. Model analysis provides implications of long-term low-carbon growth by focusing on economic effects of mitigation measures and thus offers useful information to policymakers and other stakeholders (Namazu et al., 2013). The model is used for global, regional, and national analyses, and the region of interest is usually divided into several sub-regions. In each region, a representative final demand sector and multiple production sectors are defined. The final demand sector holds capital and labor force and gets income by providing them to the production sectors. The final demand sector spends the income as a final consumption to maximize utility and as a saving for the expected future economic growth. Each production sector produces the goods using capital, labor, energy, and other materials to maximize its profit. The supply and demand are balanced at the markets for all commodities and production factors under a price mechanism. Each market is linked to those in other regions (Fujimori et al., 2012 and Fujimori et al., 2014).

AIM/Enduse covers both end-use sectors (transport, industrial, residential, and commercial) and energy supply sector. In addition, non-energy sectors (e.g., agriculture, industrial process, and waste) are included in order to assess the feasibility of achieving GHG emission reduction targets. In each sector, service demand, such as steel production, space heating in commercial building, and passenger transport, is given exogenously and technologies are selected in order to minimize the total system cost (annualized capital cost, operations cost, energy cost, and carbon price). Technology in the power generation sector is selected subject to electricity demand derived from end-use sectors. As end-use and power generation sectors are interlinked, the carbon intensity of electricity also affects technology selection in end-use sectors with explicit carbon price (Oshiro et al., 2016).
AIM/ExSS is an accounting-type model and mainly covers GHG emissions from the energy sector. The model is intended for use on a national/sub-national scale and in the first stage of backcasting. The purpose is to describe a desirable goal or socio-economic vision for a future year, and therefore it is a static model. It is an integrating tool of future economic, industrial, social, and energy visions together with mitigating options. It includes tools to estimate the consistency of socio-economic indicators and carbon dioxide emissions. The researchers often use this model in close cooperation with policymakers and other stakeholders. Through repeated calculations and discussion, the necessary levels of implementation and emission reduction by the mitigation options are assessed and a list of potential low-carbon measures is constructed (Gomi, 2016).

The agriculture, forestry, and other land use (AFOLU) sectors are one of the largest sources of anthropogenic GHG emissions in Asian countries because their domestic economies greatly rely on these sectors. In Indonesia, for example, more than 60% of the total GHG emissions come from agriculture, land use, and peat fires (Ministry of Environment, Indonesia, 2010). Mitigation measures in these sectors are therefore expected to play an important role in reducing Asia’s GHG emissions. A bottom-up type model, named AFOLU, is used to estimate GHG emissions and mitigation potentials in the AFOLU sectors based on detailed information of specific mitigation countermeasures. The emissions and mitigations are calculated under several marginal abatement costs and are based on exogenously provided future scenarios of production in agriculture and livestock industries and area of land use change. The model considers mitigation measures corresponding to major emission sources, such as livestock enteric fermentation, manure management, land use change, forestry, managed soils, and rice cultivation (Hasegawa and Matsuoka, 2015).

IV. ACTIONS AND TRANSITION PATHWAYS TOWARD LCS

Transformation to LCS needs integration of actions and initiatives at various levels. International initiatives such as IPCC and UNFCCC provide a global target, dissemination of science-based evidence and action plans, and platforms for resolving inter-country differences and building consensus. National initiatives such as Intended Nationally Determined Contributions (INDCs), carbon tax, and emission trading drive the reduction of domestic GHG emissions. Local initiatives such as city-level action plans, NGO activities, and demand-side private actions contribute to reduction of energy demand and emissions at local levels.

These initiatives cannot be separated. For example, INDC is a national initiative to reduce GHG emissions while it is requested by UNFCCC. Initiatives by local stakeholders often take place within the guideline set by a national policy framework. A public-private partnership offers an approach to accelerate transition to a LCS involving various stakeholders. Modeling tools can support the development of action plans and roadmaps for each level and initiative.

A. Ten LCS actions in Asia

Although countries in Asia have varying characteristics, there are many common LCS actions applicable to most of them. The Low-Carbon Asia Research Project (2013) proposed ten common actions and quantified their effectiveness of reducing emissions using the AIM/CGE model. The ten actions are listed in Figure 3.

It was demonstrated that Action 5 (Biomass) and Action 6 (Energy System) could contribute to about 42% of the total GHG reduction in Asia in 2050. Energy-saving activities and applications of renewables such as solar photovoltaic (PV) and wind power are the key to reduction of GHGs. The use of renewable energies will also improve energy access, eliminate energy poverty, and establish sustainable local energy systems. As biomass production and use is dispersed, global scale research and development of biomass energy resources and conversion technologies, and the transfer of technology and best practices, is vital to provide the supply-push ahead of the development of a global biomass market.

Action 1 (Urban Transport), action 2 (Interregional Transport), action 3 (Resources and Materials), and action 4 (Buildings) directly related to demand-side options could contribute to
about 36% reduction in 2050. Action 1 includes compact city designs with well-connected hierarchical urban centers, a hierarchical urban public transport system, low-carbon vehicles (using electricity, biofuels, and natural gas), and efficient road-traffic management systems. Hierarchical urban transport systems are designed to reduce transport demands and increase comfortability by connecting various transport modes such as railways and bus rapid transit and private vehicles (Low-Carbon Asia Research Project, 2013). Action 2 includes forming industrial corridors with low-carbon transport systems, establishing inter-modal transport systems linking rail and water, and reducing the use of aircrafts and fossil-fuel vehicles. Action 3 includes incorporating new and efficient production process technologies that reduce the use of materials, extending the life-span of products, and developing systems to reuse material resources. Action 4 includes improving the energy efficiency of buildings, application of high-efficiency equipment—especially for heating and cooling—and providing visibility and incentive to energy saving efforts.

Action 7 (Agriculture and Livestock) and action 8 (Forestry and Land Use) could contribute about 12% of emission reduction in 2050. Action 7 includes actions by farmers such as efficient water management in rice paddies, efficient fertilizer application and residue management, and recovery and use of methane gas from livestock manure. Action 8 includes forest protection and plantation, sustainable peatland management, and monitoring and management of forest fires. Action 9 (Technology and Finance) and action 10 (Governance) do not directly contribute to emission reduction but support planning and implementation of other actions as they are concerned with governance, funding, and technology transfers.

The model outputs showed that GHG emissions in Asia can be reduced by 20 Gt of CO₂ equivalent, i.e., by 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 borne in mind that we need smart strategies and knowledge sharing in each country depending on its development stage.

B. Country level LCS actions

Mittal et al. (2016) assessed the implication of aligning the renewable energy deployment target with the national emission reduction target for mitigation cost. The assessment methodology uses the AIM/CGE model to determine the mitigation cost in terms of GDP loss under alternative renewable targets in different climate-constrained scenarios. Comparative results show that China needs to increase its share of non-fossil fuel in the primary energy mix to a greater extent than India in order to achieve the stringent emission reduction target. The mitigation cost in terms of economic loss can be reduced by increasing the penetration of renewable energy to achieve the same emission reduction target. The results show that coordinated
national climate and renewable energy policies help to achieve the GHG emission reduction target in an efficient and cost-effective manner.

Jiang et al. (2016) analyzed paths for China compatible with the global 2°C target. To meet the target, China needs to peak its CO₂ emissions by 2025 at the latest and then undertake deep cuts by 70% or greater by 2050 compared to 2020. Although it is a huge challenge for China, the modeling study shows that it is feasible if sufficient domestic action is taken together with international collaboration, and progress is made in technology development. Renewable energy development policies are crucial for China to reach the 2°C target.

Shukla and Dhar (2016) projected GHG emission pathways in India through the year 2050 using ANSWER-MARKAL and a soft-linked integrated model system (SLIMS). SLIMS includes multiple models such as AIM CGE, AIM ExSS, and others that are externally linked through transfer of certain parameters. They presented low carbon transition in India from two different perspectives. The first perspective is the conventional low carbon scenario (CLCS), which assumes that the rest of the economy is in competitive equilibrium and ignores institutional weakness of developing countries. This 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 a global emission carbon cap. They propose a second scenario, referred to as sustainable low carbon scenario (SLCS), that explicitly recognizes market weakness and hence implements additional policies that align the national sustainable development goals with the global low carbon objective. In SLCS, the emissions are first reduced by various measures targeted to achieve national sustainable development goals. The assessment 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.

Oshiro et al. (2016) assessed the feasibility of decarbonization pathways up to 2050 and their effects on energy security, considering the latest energy and climate policies in Japan (METI, 2015), using the AIM/Enduse model. For countries without sufficient fossil fuel resources such as Japan, renewable energies could play a major role in replacing fossil fuels in the long term and thus contribute to satisfying both climate and energy security requirements, even if the availability of nuclear power remains highly constrained until 2050. However, in the mid-term, the potential of renewable energies is insufficient to eliminate fossil fuels; therefore, the absence of nuclear power will impact energy security. Thus, policies in the mid-term will still require enhancement of the energy security of fossil fuels, including diversification of fuel sources and supply routes and alleviation of price volatility impacts.

Thepkhun et al. (2013) analyzed GHG emission measures under emission trading and carbon capture and storage (CCS) technologies in Thailand using the AIM/CGE model. Results show that an international free emission trading policy can drive significant GHG reduction by decreasing energy supply and demand and increasing prices of emissions. The CCS technologies would balance emission reduction, but they would reduce energy efficiency improvement and renewable energy utilization. As co-benefits, these measures would improve energy security, reduce energy import dependency, and improve local air quality (Thepkhun et al., 2013).

Limmeechokchai (2016) assessed the feasibility of implementing Thailand’s Nationally Appropriate Mitigation Action (NAMA). The results show that Thailand has a high potential of GHG emission reduction. Both domestically and internationally supported NAMAs could lead to 23–73 million tonnes CO₂ reduction (or 7%–20% of GHG emissions) in 2020. The NAMAs include measures in the areas of (1) renewable electricity, (2) energy efficiency, (3) biofuels in transportation, and (4) environmentally sustainable transport system. The suggested GHG countermeasures are in line with the national policy and plans of ministries of energy and transport in order to avoid conflict between climate policy and policies of the related ministries. The author also emphasized that it is important to communicate the results of cost optimization, co-benefits, economics, and appropriateness among policymakers, administrators, researchers, and the public for consensus building.

In an analysis of mitigation potential in agriculture and land use sectors in Indonesia, Hasegawa and Matsuoka (2015) reported a technical mitigation potential in the agriculture sector of 52 MtCO₂eq/year in 2030 or 67% of 2005 agricultural emission. Cumulative technical
mitigation potential up to 2070 in the land use sector is reported at 16 GtCO₂. They suggest that evaluation of mitigation effects, setting reduction targets, costs, and application schedule from a long-term viewpoint will help to increase mitigation potential.

C. Local and city level actions

Several sub-national level LCS studies have been carried out with a view to explore mitigation options that are closer to ground level realities and actions which local stakeholders could undertake. Evidently, most of such scenarios have shorter horizon than national and global scenarios. Here, we present the findings of LCS scenarios for the region of Iskandar (Malaysia) and Ho Chi Minh (Vietnam). Several other scenarios are published on the 2050 low carbon scenario website (AIM, 2016).

The UTM-Low Carbon Asia Research Center published “The Low Carbon Society Blueprint for Iskandar Malaysia 2025” (Ho and Matsuoka, 2013). This LCS blueprint is a set of workable development policies in the form of 12 Actions, over 280 Programs, and a roadmap for implementation. The results from modeling and analysis show that in the LCS scenario, it is possible to achieve 58% reduction in GHG emission intensity and 40% reduction in emissions by 2025, as compared with business as usual (BaU). Countermeasures are based on technologies such as energy-efficient equipment in all sectors, photovoltaic (PV) power generation, biomass utilization, and energy-efficient buildings. They also include urban planning policies such as modal shift, compact city development, and behavioral changes in the communities through education campaigns.

Ho Chi Minh City has developed the “Climate Change Action Plan in the 2016–2020 period with a vision towards 2030.” Two scenarios were developed for the socio-economic vision of Ho Chi Minh City by 2020. In 2020 BaU, the total GHG emissions increase 1.75 times compared to 2013 and the share of energy-related GHG emissions is 95.1%. The emission could be reduced by about 20% through low carbon activities such as energy efficiency improvement by the Energy Service Company (ESCO) project, enhancement of renewable energies, waste management, and land-use planning (Low Carbon Project Team for Ho Chi Minh City, 2016). These activities involve the sectors of energy generation, energy distribution, and urban development.

D. Costs of LCS actions

Cost and related economic impacts of mitigation actions and LCS transformation pathways are of as much interest to the stakeholders as emission impacts and technical feasibility. Integrated assessment models and scenarios are helpful in providing estimates of such impacts as well. Depending on their methodology, the particular models calculate economic impacts in terms of some of the following indicators: GDP or consumption loss (typically expressed as percentage of economic output), carbon price and marginal abatement cost, welfare loss, additional capital investment cost (often in energy or power sector), energy system cost, import bill, and others. Like emission mitigation results, the economic impacts are often expressed for the world, region, or country in comparison with a reference scenario (baseline) or a reference year. However, these economic impact estimates are subject to several assumptions about parameters like future population, economic growth, capital costs of technologies (and their learning curves), energy costs, trade regimes, discount rates, correlation between carbon price and mitigation cost, domestic and international environment policy regimes, and assumptions behind the baseline scenario. In addition, they may not fully reflect the effects of inter-linkages among different sectors, interactions between mitigation, adaptation, and climate impacts, and co-benefits and adverse side-effects from mitigation such as impacts on land use and health benefits (IPCC AR5, 2014). Even direct economic benefits from reducing climate change are often not included in the analysis. Some studies attempt to overcome this limitation by estimating certain inter-linkages such as the impact of renewable energy investment on reducing GDP loss or the effect of recycling carbon tax to subsidize low carbon energy.
The literature is replete with model based estimations of economic impacts under mitigation scenarios. While on the one hand these models suffer from several of the limitations listed above, on the other hand different models report varying results owing to differences in assumptions. Here, we cite only a few selected sources for the purpose of providing an indication of the type of measures and their magnitude.

A robust result across different models and studies is that aggregate carbon price and global costs of mitigation increase over time and with stringency of mitigation or concentration goal. Since different models have different assumptions about capabilities for deep emission reduction, the inter-model variability in the carbon price and cost increases as well. According to the implementation scenarios in the WG III AR5 Scenario Database, global consumption loss ranges between 1% and 4% in 2030, 2% and 6% in 2050, and 3% and 11% in 2100 relative to consumption on baseline, for reaching levels of 430–480 ppm CO$_2$eq concentration by 2100 (IPCC AR5, 2014). A similar trend, i.e., increasing mitigation cost with time and with stringent targets is also reported by Fujimori et al. (2016a) in an assessment of shared socioeconomic pathways.

Assessing long term climate mitigation goals in the context of Paris Agreement, Fujimori et al. (2016b) report a high global GDP loss of 2% in 2050 in 450 ppm stabilization scenarios that entail drastic emission reduction in early years (by 2020) and 2%–3.2% in 2100 in different early reduction and late reduction 450 ppm scenarios. The carbon price in 2100 is lower in the early reduction scenario (650 USD/ton-CO$_2$eq) than in the late reduction scenario (3000 USD/ton-CO$_2$eq), partially because the marginal emission reduction space to achieve the 450 ppm level is limited after 2070.

In an analysis of decarbonisation pathways in Japan up to 2050, Oshiro et al. (2016) report a reduced energy import bill due to improvement of energy efficiency and development of renewable energy. However, the import bill remains high (at 1.4%–1.5% of GDP) until 2030 since renewable energy expansion options are limited in the short term. Post 2030, the import bill reduces significantly and reaches 0.5%–0.6% of GDP, as a result of a rapid rise in renewable energy.

In a comparative study of scenarios for China and India that align the domestic renewable energy development target with the national emission mitigation target, Mittal et al. (2016) report that mitigation cost in terms of economic and welfare loss can be reduced in both countries by increasing the penetration of renewable energy to achieve the emission mitigation target. For a strong carbon constraint, they estimate carbon price in 2030 at 103–233 USD/ton-CO$_2$ in China and 119–182 USD/ton-CO$_2$ in India. The price falls by 5%–20% as renewable capacity increases. They observe that the GDP and welfare gain or loss in a high renewable energy scenario depend on the net effect of two factors—the lowering of carbon price and electricity price, on the one hand, and the high capital intensity of renewable energy on the other, implying less capital availability for other sectors. For a strong carbon constrained scenario with high development of renewable energy, GDP loss and welfare loss in 2030 are estimated at about 7.5% and 12.5%, respectively, for China and about 3.7% and 5.5%, respectively, for India.

V. PROCEDURES FOR DESIGNING AND IMPLEMENTING LOW CARBON POLICIES

UNFCCC shall periodically take stock of the implementation of Paris Agreement (UNFCCC, 2015). The PDCA cycle, which is an iterative management method aimed at continuous improvement of a process, can support the design and implementation of GHG reduction strategies.

The PDCA cycle is a systematic series of steps for gaining valuable learning and knowledge for the continual improvement of a product or process. Also known as the Deming Wheel or the Deming Cycle, it was developed by Deming based on the Shewhart theory for the quality control of industrial processes and has been subsequently applied to various fields (Deming, 1986; Rita and Lakshmi, 2009; and Gustafsson et al., 2015).
It consists of designing a plan ("Plan" phase), implementing it ("Do" phase), checking the outputs and outcomes ("Check" phase), and modifying and/or designing the plan for further implementation ("Act" phase).

When utilizing the PDCA cycle, users have to consider its hierarchical structure deriving from the difference in the levels of entities in charge of implementation. For example, an activity for GHG reduction requires detailed elucidation in the “Plan” phase by the concerned government agency and other stakeholders. Actions, policy measures, and roadmaps designed based on analysis using integrated assessment models can support the “Plan” phase. The “Do” phase involves a lot of execution work including implementing the policies and actions, monitoring their performance, amending them based on ex-post evaluation, and repeating or improving them. Results of actions by each stakeholder are checked in the “Check” phase. Plans are modified based on the results of evaluation ("Act" phase) on monthly or yearly basis. When a comprehensive amendment is required, activities conducted in the “Act” phase are similar to the activities in the “Plan” phase. This whole process can be regarded as an activity in the “Do” phase from the viewpoint of the upper layer of the PDCA cycle, which is often managed by a different government agency.

The PDCA cycle can be subdivided into several layers. Tasks required for each step are common to different layers, but the actors who pursue the PDCA cycle, the level of detail, and cycle times are different. The entity in charge of each action or program/measure should design every activity, consider staffing, budgeting, and scheduling for implementation, and summarize them in a document at the plan phase. It implements and operates the activities according to the plan and monitors the indicators that represent progress of each activity at the “Do” stage. An activity is evaluated based on its achievement, and decision is taken about its continuation, improvement, or suspension at the “Check” stage. The entity should amend (or suspend in some cases) the document prepared in the “Plan” stage according to the results of evaluation at the “Act” stage (Gomi and Matsuoka, 2015).

VI. CONCLUSION

It is clear that much more drastic and early actions than being presently undertaken are needed to limit the average global temperature increase to 1.5°C above pre-industrial levels. The Asian region, accounting for a significant portion of global GHG emissions and growing at a rapid economic pace, has a major role to play in the world’s transition to LCS.

To understand and design LCS policies, it is important to have a scientific backup that can provide LCS pathways and effectiveness of policies to achieve them under different scenarios. The AIM model, one of integrated assessment models, can support these analyses.

The AIM is a tool to provide pathways to a LCS while considering consistency among sectors and policies. It can provide comprehensive assessment of various policies, including macro-economic policies and technological measures. It can analyze trade-offs between rapid economic growth in Asia and its environmental impact and assess sustainable development policies.

The experience of the AIM team in working with researchers from diverse Asian countries suggests that it is important for researchers to provide their own country’s LCS scenarios in close cooperation with policymakers and other stakeholders.

LCS scenario analyses and projects involving collaboration among researchers and policymakers in different Asian countries have shed valuable insights into LCS actions and policies at the country and local levels. Common actions include supply-side measures like renewable energy technologies; demand-side actions like efficiency improvement, redesign of cities and public transportation infrastructure and buildings; technology and natural resource management in agriculture, land use, and forestry; and cross-cutting institutional actions related to financing, governance, and technology transfer. These analyses with AIM could enhance science and policy linkages and provide feasible pathways to a LCS.

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