Summary

The United Nations has estimated that about half of the 6.5 billion world population currently lives in cities. Moreover, an additional 1.8 billion people will move to urban areas by the year 2030. Understanding the relationships between energy use pattern and carbon emission development is crucial for estimating future scenarios and can facilitate mitigation and adaptation of climate change. This paper investigates the development pathways on selected Southeast Asian cities, including Bangkok, Hanoi, Jakarta and Manila, which are major cities in the region in terms of energy consumption, carbon emissions, and climate policies. The paper investigates the development of energy and carbon emissions, and climate change mitigation strategies of the selected case studies. In addition, the paper attempts to estimate the energy consumption and associated carbon emissions. Then, it compares overall patterns of selected cities and analysis of the climate policies.

**Key Words:** Carbon Emissions, Climate Policies, Energy Consumption, Southeast Asian Cities
1. INTRODUCTION

The United Nations has estimated that about half of the world’s 6.5 billion people currently live in cities. Moreover, an additional 1.8 billion people will move to urban areas by the year 2030. Southeast Asia contributed 12% of the world’s total greenhouse gas (GHG) emissions in 2000, amounting to 5,187.2 Mt CO₂-eq, including emissions from land use change and forestry. The region’s total emissions increased 27% during 1990-2000, faster than the global average rate of increase. On a per capita basis, the region’s emissions are considerably higher than the global average, but are still relatively low when compared to developed nations. Furthermore, the region’s GHG emissions from the energy sector grew by 83% during the same period, the highest growth rate among three major sources of emissions (i.e. land use change and forestry, energy and agriculture) (ADB 2009).

Cities are both drivers and targets of climate change. Cities are the engines of economic development of a country, as well as centres of key activities that drive changes in the carbon cycle and climate system. Despite the importance of cities, they have not been a unit of analysis for energy and carbon emissions in past decades. This is particularly true for Southeast Asian cities where rapid economic growth has led to rapid increases in energy consumption and carbon emissions. As a consequence of urban expansion, Southeast Asian cities will require an enormous amount of resources and will emit more emissions.

Understanding the relationship between energy use pattern and carbon emissions is crucial for estimating future scenarios, and can facilitate mitigation and adaptation to climate change. The main research questions are: How have past and current trends in energy consumption and carbon emissions developed over time in major Southeast Asian cities? What are the future scenarios of the target cities? How do city officials respond regarding climate change policies? What policy measures have been implemented to influence mitigation in selected cities? To address these questions, a comparative study of development pathways for select Southeast Asian cities in terms of energy consumption, carbon emissions, and climate policies, has been conducted. The study is focused on four cases: Bangkok, Hanoi, Jakarta and Manila, which are major cities in the region and can contribute to large extended energy-saving opportunities and carbon emission reductions as well as regional development.

The paper investigates a range of socio-economic aspects that influence energy consumption and energy-related CO₂ emissions, and energy and climate policies. In addition, the paper attempts to estimate future scenarios of energy consumption and associated CO₂ emissions. The study focuses on an analysis of the development pathways of energy consumption and energy-related CO₂ emissions. Then, it compares overall patterns of the selected cities.
Main findings of the case studies can contribute to underpin more efficient energy utilisation, carbon emission reductions, and enhancing sustainable development at city, national and regional levels. This study can also help to understand ongoing processes and develop means on how to react strategically to climate change.

2. DRIVING FACTORS IN ENERGY CONSUMPTION AND EMISSIONS

In principle, energy use and associated emissions in a city are generated by three kinds of activities. The first type is produced through direct energy consumption or direct emissions within the boundary of a city itself (e.g. gasoline or diesel combusted by vehicles). The second type is indirect energy consumption or indirect emissions, which is encompassed those types of energy use in a city where energy is used inside a city with the actual emissions taking place outside its boundary (i.e. electricity generation). The third type of activity is embodied energy or embodied emissions. This activity is due to energy use and environmental emissions taking place outside of the city to produce goods and services consumed within the city (Dhakal 2008).

Factors driving energy consumption and associated emissions in cities have been interpreted differently among research communities. Engineers typically look at the contributions of various energy sectors (i.e. residential, commercial, industrial and transport sectors) as well as the energy mix in an energy system. Economists see the energy use and emissions linkages to income, elasticity, market role, price, etc. Social scientists see the drivers from a wider perspective. Dhakal (2008) has summarised different approaches to explain such drivers as following.

\[
\text{Emissions} = \text{sum (sectoral and subsectoral disaggregations)}
\]

\[
\text{Emissions} = f \ (\text{emission/energy, energy/income, income/person, population})
\]

\[
\text{Emissions} = f \ (\text{economic growth, price signal, externality, market mechanism})
\]

\[
\text{Emissions} = f \ (\text{population, organisation, environment, technology, institutions, culture})
\]

\[
\text{Emissions} = f \ (\text{mobility, shelter, food, lifestyle})
\]

A strong correlation between emissions, population and gross domestic product (GDP) reflects the importance of population and economic growth as emission drivers. Figure 1 presents an overall picture of urbanisation rate
in selected Southeast Asian countries. It is projected that in the year 2020 the population in Bangkok, Hanoi, Jakarta and Metro Manila will reach 7.76, 5.78, 20.77 and 13.4 millions, respectively (ADB 2008).

Previous studies have used decomposition analysis to analyse the importance of population, income, energy intensity and fuel mix shifts in shaping energy-related emission trends. A comprehensive global study on factors contributing to CO₂ emissions can be found from Baumert et al., 2005. It should be noted that the drivers of CO₂ emissions are very complex and multifaceted. These drivers are raising the challenge to greater in-depth analysis, particularly at a city-scale.

FIGURE 1
Trends of Urbanisation Rate in Selected Southeast Asian Countries

In Southeast Asian cities, the major driving forces behind energy consumption and CO₂ emissions are related to urban demographic changes, income level and lifestyle, socio-economic development, urban spatial structure and transportation system, energy technologies, and local climate factors. An understanding of these factors is essential to formulating policy measures in achieving co-benefits of reducing energy consumption and impacts of climate change. Some previous studies discussed the drivers that influence energy consumption and emissions from Asian cities, for example see Dhakal 2004; 2008. Impacts of some of these drivers are well established while others are not clear. Furthermore, some drivers are also dependent on location (i.e. local climate, geography, culture, etc.); therefore, an in-depth analysis of a particular city is required for a full understanding of driving factors.
3. ENERGY AND CLIMATE POLICIES

Cities in developed countries tend to make comprehensive energy and climate policies locally and in many cases have specific emission targets. Europe has been at the forefront of the attempts to reduce CO₂ emissions from cities. Many European cities are much ahead in implementing local climate policies compared with other regions.

Southeast Asian cities are likely influenced by the central government decision regarding energy and climate policies. Some cities, such as Bangkok, are raising energy and climate awareness to the residents and some cities are in the development stage. It is found that in many cases, they often show climate policy linkages through co-benefits in relation to activities in energy efficiency, energy conservation, urban air pollution and health, and land transport management. Also, many cities are interested in developing energy and climate projects for generating local revenue through Clean Development Mechanism (CDM) and selling Certified Emission Credits (CERs) to their parties. Most of the urban projects are related to improving energy efficiency, fuel switching, and waste management (Dhakal 2008).

Energy and climate policies are challenging issues, particularly at the city-scale since most of the relevant policies are designed at the national level. Currently, comprehensive policy with a focus on climate mitigation does not exist at a city level in Southeast Asia, but some cities in developed Asian nations, such as Japan (Tokyo and Osaka) and Korea (Soul), have started formulating such policies. At a national level, some Southeast Asian countries have already introduced and implemented various policies in meeting their energy and development goals, and each country has developed a specific policy framework or integrated climate concern in the overall energy and development policy framework (Table 1). It should be noted that the focus in this study is based on the existing legal measures. The study found that each case studied country has developed its own national plan and strategy for climate change and has established an agency for climate policy.

Southeast Asia has considerable potential to harness renewable resources. Indonesia, the Philippines and Thailand have elaborated specific renewable energy policy frameworks (see Table 1). Energy security is very prominent in the policy goals of these countries though environmental protection, energy access and investment promotion goals are also considered important. These policy goals reflect the concern of growing dependence on imported energy and environmental issues related to power generation, particularly in the Philippines and Thailand. In the Philippines, under the Philippine Energy Plan, the use of new and renewable energy sources is seen as significant in contributing to electricity generation. Thailand has developed the Alternative Energy Development Plan, which covers a wide range of power generation and heat production from renewable energy resources. Thai government target is to increase the
share of renewable energy to 8% by 2011. Recently, Thailand has announced a new renewable energy plan, which aims for energy from renewable sources to constitute 20% of final demand by 2022. In Vietnam, the Energy Law aims to improve energy efficiency and promotes the development of renewable sources. Renewable energy development is pursued within the context of improving energy access in rural areas. Vietnam has also recognised the relevance of renewable energy development as a least-cost option to increase electricity access in remote and isolated regions (ADB 2009).

The transport sector has high potential to reduce CO₂ emissions and improve urban air quality in Southeast Asian cities. Policies in Thailand to mitigate emissions from transportation include the development of a master plan in large cities, promoting the mass transit systems in Bangkok, encouragement of car pools, retrofitting and improvement of engine efficiencies, and promoting the use of natural gas in vehicles. Indonesia considers the development of mass rapid transportation as an important measure to reduce emissions in urban areas. The Indonesian government has developed the strategic plan for the transportation sector in response to climate change. In the Philippines, Road Transport Patrol Programme was launched to promote efficient use of fuel. Vietnamese government plans to improve fuel efficiency in transport through the wider use of cars with lean burn engines.

Mitigation of climate change requires action at all different levels from international to national and local levels. Currently, most mitigation efforts in the energy sector in Southeast Asia have focused on improving energy efficiency, developing renewable energy sources, and promoting urban mass transit systems. Cities play a crucial role in implementation of national standards. They have the capacity to issue building permits and ensure projects that meet energy regulations, and they can introduce new energy conservation rules in the plans. They also provide a platform to launch efforts to mitigate emissions which would not only result in the reductions of national emissions but also would bring benefits at local scale. In the near term, policy changes in Southeast Asian cities would be required to begin the shift of development patterns in a manner that moves toward low-carbon cities, and avoids some of the most adverse climate change impacts.

In addition to the supply and demand-side policies, the embodied energy policy due to consumption-based activity should be considered, since cities are a centre of consumption activity, particularly large cities. Instead of focusing on emissions produced within the city’s border, many studies argue that a consumption-based responsibility would be more equitable as the necessary deep cuts in emissions, since it takes into account trade, emphasizes demand-side action, prevents carbon leakage, and provides a stronger rationale for low-carbon technology transfer and deployment in developing countries (Wang and Watson 2008). A consumption-based emissions account might also help the developing countries to negotiate in the post-2012 climate agreement as strategic emission reductions measure.
TABLE 1
Major Energy and Climate Policies in Selected Southeast Asian Countries

<table>
<thead>
<tr>
<th>Case studies</th>
<th>Relevant policies at national and city levels</th>
<th>Key policy measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok (Thailand)</td>
<td>The Energy Conservation Promotion Act (ENCON Act) – passed in 1992, is the primary legislation guiding Thailand’s energy conservation and renewable energy policy.</td>
<td>• compulsory programmes • voluntary programmes • regulation • building code • labels • energy performance standards • financial incentive</td>
</tr>
<tr>
<td></td>
<td>National Strategy on Climate Change – approved in 2008</td>
<td>• information • capacity building • research and development</td>
</tr>
<tr>
<td></td>
<td>Strategic Plan for Renewable Energy Development – issued in 2003, aims to increase the share of renewable energy in the primary energy consumption to 8% in 2011</td>
<td>• renewable portfolio standard, 5% of new power plants must be generated by renewable energy • investment incentives • tax measures • net metering regulations • public-private partnerships • feed-in tariffs</td>
</tr>
<tr>
<td></td>
<td>Bangkok Metropolitan Administration Action Plan on Global Warming Mitigation 2007 – 2012, set a target to reduce carbon emissions by 15% per year from 2007-2012</td>
<td>• information • voluntary programmes</td>
</tr>
<tr>
<td>Hanoi (Viet Nam)</td>
<td>National Energy Policy (2004) – providing electricity services in the rural areas and support an acceleration of renewable electricity production.</td>
<td>• foreign or local investment for off-grid supply</td>
</tr>
<tr>
<td></td>
<td>National Energy Efficiency Programme 2006-2015 – approved in 2006, aims to reduce 3%-5% of total energy consumption by 2010, and 5%-8% reduction by 2015</td>
<td>• information • scientific and technological activities • voluntary labels</td>
</tr>
</tbody>
</table>
### Table 1, continued

<table>
<thead>
<tr>
<th>Case studies</th>
<th>Relevant policies at national and city levels</th>
<th>Key policy measures</th>
</tr>
</thead>
</table>
| Jakarta (Indonesia) | The Energy Law – promulgated in 2007, is ruled important institutional and legal changes on Indonesia’s energy policy. | - financial subsidies  
|                     |                                              | - regulation  
|                     |                                              | - information and training  
|                     |                                              | - voluntary labels  
| National Energy Policy – issued in 2004, sets a 5% target of renewable energy in power generation by 2020. | - power purchase programme for small-scale power generation  
|                     |                                              | - renewable energy targets  
|                     |                                              | - feed-in tariffs  
|                     |                                              | - voluntary corporate efforts  
| National Action Plan for Climate Change |                                              | - guide for climate change mitigation and adaptation efforts  
| Manila (the Philippines) | Renewable Energy Policy Framework – issued in 2002, aims to reduce the country’s dependence on imported energy, broaden resource base, and save foreign exchange and reduce emissions. | - renewable energy targets  
|                     |                                              | - regulating in geothermal, mini-hydro and wind  
|                     |                                              | - tax measures  
|                     |                                              | - public-private partnerships  
|                     |                                              | - voluntary corporate efforts  
| Department of Energy Act – issued in 1992, an Act creating the department of energy rationalising the organisation and functions of government agencies related to energy and for other purposes. | - financial subsidies  
|                     |                                              | - tax incentives  
|                     |                                              | - regulation  
|                     |                                              | - energy performance standards  
|                     |                                              | - mandatory product labels  

4. ENERGY USE AND CO₂ EMISSIONS IN SELECTED CITIES

4.1 Definition of the Case Studies

Data from disparate reports and studies can sometimes be incompatible because different definitions of a city are employed. To remedy this problem, this paper uses the definition of a city based on local administrative definitions. Table 2 provides basic indicators of the case studies (Bangkok, Hanoi, Jakarta and Manila), while Table 3 shows the population estimates and projections.

### TABLE 2
Basic Indicators of Case Studies

<table>
<thead>
<tr>
<th>City</th>
<th>Population in 2005 ('000)</th>
<th>Economic Product in 2004 ($M)</th>
<th>Land Area (sq. km)</th>
<th>Population Density (people/sq.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok</td>
<td>5,483</td>
<td>63,088</td>
<td>1,569</td>
<td>3,495</td>
</tr>
<tr>
<td>Hanoi</td>
<td>3,183</td>
<td>NA</td>
<td>921</td>
<td>3,348</td>
</tr>
<tr>
<td>Jakarta</td>
<td>8,864</td>
<td>24,592</td>
<td>661</td>
<td>13,397</td>
</tr>
<tr>
<td>Metro Manila</td>
<td>10,677</td>
<td>32,277</td>
<td>636</td>
<td>17,453</td>
</tr>
</tbody>
</table>

NA – not available. Source: UN-HABITAT Database.

Bangkok is governed by the Bangkok Metropolitan Authority (BMA) with a total land area of 1,568 km². Bangkok consists of 50 districts and 154 sub-districts. It is the overwhelming centre of culture, population and economic development for Thailand.

Hanoi city lies in the centre of the Hanoi region on the bank of Red River. Hanoi is an administrative area consisting of nine urban districts and five suburban/rural districts. It has a land area of 921 km². Hanoi today is experiencing rapid economic growth and industrial expansion.

Jakarta is located in a low land area with average height around 7 m above sea level and comprised of 661 km². Jakarta is divided administratively into six municipalities. It is inhabited by variety of races and tribes, with different socio-cultural background both in terms of population size and economics.

Metro Manila is composed of four districts with twelve cities and five municipalities. It contributes 30% of the Philippines’ GDP. Metro Manila also provides almost half of the total national output in manufacturing, commerce and services. Metro Manila accounts for about 13% of the country’s total population.
### TABLE 3
Population Estimates and Projections in Case Studies

<table>
<thead>
<tr>
<th>City</th>
<th>2010</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangkok</td>
<td>6,918</td>
<td>7,807</td>
<td>8,332</td>
</tr>
<tr>
<td>Hanoi</td>
<td>4,723</td>
<td>6,036</td>
<td>6,754</td>
</tr>
<tr>
<td>Jakarta</td>
<td>9,703</td>
<td>11,689</td>
<td>12,363</td>
</tr>
<tr>
<td>Manila</td>
<td>11,662</td>
<td>13,892</td>
<td>14,808</td>
</tr>
</tbody>
</table>

Source: UN 2007.

### 4.2 Comparison of Energy and Emissions

Cities offer major opportunities to reduce energy demand and to mitigate the impact of global climate change, just as they drive the economy of their nations. Cities that are not properly planned or managed can be a burden on natural resources and threaten quality of life. Cities and urban activities are usually blamed for global increases in GHG emissions, but UN-HABITAT (2008) analysis shows that the emissions from cities are more related to consumption patterns and income per capita (i.e. GDP/capita) rather than the urbanisation levels. When comparing cities' energy use and carbon emissions, it is important to discuss the complexities involved, not only the size of an economy, its transport, and household consumption pattern.

According to the Asian Development Bank study team (ADB 2009), the four countries emitted a total of 544 Mt of energy-related CO₂ emissions in 2000. They consumed a total of 193 Mtoe of primary energy, including 113 Mtoe of oil (58%), 47 Mtoe of natural gas (24%), 30 Mtoe of coal (16%), and the remaining 3 Mtoe (2%) from renewable energy.

In this study the emission performance of cities is measured in terms of CO₂ emissions per capita. Emissions per capita is a better indicator than emissions alone because it internalises some of the equity debates (Dhakal 2008). A comparison of energy and associated CO₂ emissions from Bangkok, Jakarta and Manila is shown in Figure 2.

A limitation of this study is a lack of sound data on urban energy consumption. Because disaggregated data is not available, it is not clear what proportion of the overall emissions is generated in urban areas, although since most buildings and transport networks are located in cities, urban areas are most likely responsible for a large proportion of these emissions (UN-HABITAT, 2008). It is important to understand which sectors consume the most energy to take appropriate actions for emission reductions.
4.3 Urban Transport

Transport sector is a major contributor of CO₂ emissions in the case studies. Rapid growth in urban population has contributed to high growth in demand for transport services and energy consumption. This sector also emits other pollutants such as NOₓ, SO₂, CO, particulate matter, etc. into the atmosphere. These gases lead to worse air quality in urban areas. The four case studies have established plans to expand and introduce mass transit systems or to develop road infrastructure in order to alleviate congestion and improve the overall energy efficiency of urban transport.

Figure 3 shows trends in number of registered vehicles in the case studies. In Bangkok, Jakarta and Manila, the modal share of public transport varies between 40% and 60% of total person trips (Nhan 2008). By contrast, in Hanoi the percentages of individual private motorcycles and bicycle are extremely high, which accounts for 60% and 30%, respectively (Hoang, 2004). Table 4 presents the structure of current and estimated future energy demand in transport sector.

Bangkok has two mass rapid transit (MRT) systems: the Sky Train and Subway. Sky Train has 23 km of elevated track that transports about 400,000 passengers per day. The subway is an underground route of 20 km that transports around 20,000 passengers daily. BMA is extending the Sky Train in several phases with a total length of 7.5 km extension. Bangkok also plans to extend existing MRT lines, amounting to a total of 118 km by 2020. Moreover, Bangkok is developing a bus rapid transit system that is expected to carry 50,000 passengers daily.

Hanoï’s transport is now characterised by motorcycles and rapid growth in passenger vehicle ownership. Buses account for a small portion of total personal transport.
trips. According to the master plan, Hanoi will develop a transport system that can accommodate the increasing number of passengers. Hanoi aims to increase the density of its urban road network.

Jakarta is dependent on road transport. Passenger vehicles account for about 11% of total personal trips, while buses account for 52% of total personal trips. According to a transport master plan, Jakarta aims to reduce its congestion problem and energy consumption as well as CO₂ emissions through investment in road infrastructure and the development of MRT systems.

Currently, Manila has three MRT systems in operation, including one MRT and two light rail transit (LRT) systems. Manila plans to expand the existing lines and further develop the LRT systems. As part of a plan to reduce congestion and manage transport efficiently, Manila plans to develop two rails that connect the city centre to suburban areas.
### TABLE 4
Structure of Fuel Share and Estimated Energy Demand from the Urban Transport Sector

<table>
<thead>
<tr>
<th></th>
<th>Fuel Share (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bangkok</td>
<td>Jakarta</td>
<td>Manila</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>Gasoline</td>
<td>48.9</td>
<td>50.1</td>
<td>55.2</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>43.9</td>
<td>49.0</td>
<td>44.3</td>
</tr>
<tr>
<td></td>
<td>LPG</td>
<td>6.1</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>0.1</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Electricity</td>
<td>1.1</td>
<td>NA</td>
<td>0.5</td>
</tr>
<tr>
<td>Total energy demand (10^6 GJ)</td>
<td>180.4</td>
<td>242.5</td>
<td>93.3</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>Gasoline</td>
<td>56.9</td>
<td>48.0</td>
<td>48.4</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>38.9</td>
<td>51.1</td>
<td>51.4</td>
</tr>
<tr>
<td></td>
<td>LPG</td>
<td>3.5</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>0.1</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Electricity</td>
<td>0.7</td>
<td>NA</td>
<td>0.1</td>
</tr>
<tr>
<td>Total energy demand (10^6 GJ)</td>
<td>347.6</td>
<td>571.7</td>
<td>598</td>
<td></td>
</tr>
</tbody>
</table>

LPG stands for Liquefied Petroleum Gas and CNG stands for Compressed Natural Gas.

5. **SUMMARY**

Cities are not just victims of climate change but also part of the problem, which means they are also part of the solution. Cities in the developing world show different energy end-use distribution according to their size and stage of economic development. The case studies show that they are not only engines of their representative countries’ economic growth, but also of the regional economies. Factors driving energy consumption and energy-related emissions in cities are interconnected in many respects. The challenges are to create knowledge based policies and to implement energy conservation and mitigation practices. Better scientific knowledge is a prerequisite for understanding the various causes of emissions and for implementing such measures.

Cities in Southeast Asian countries are continuing to grow due to changes in urban demographics, income level, lifestyle and related socio-economic devel-
This study shows that the projected population in Bangkok, Hanoi, Jakarta and Metro Manila will reach 7.76, 5.78, 20.77 and 13.4 million, respectively, by the year 2020. This will lead to intensive energy consumption in urban areas. In terms of per capita energy consumption and CO₂ emissions, Bangkok is the highest in the region. In terms of sectors, transportation is the largest energy consumer in these cities. Strategies to reduce transportation-related energy consumption and CO₂ emissions include modal shifts to mass transit, urban planning and public transport, and fuel economy standards. Many initiatives have been introduced and implemented to achieve co-benefits of reducing energy consumption and improving urban air quality.

The way cities are designed and managed over the coming decades will have a large influence on the future of the carbon cycle both locally and globally. Well-designed and well-managed cities provide many opportunities to reduce per capita energy consumption and/or carbon emissions. Carbon management would play an important role in the city's climate policy. A key need in these efforts is to develop a science-based policy and implementing framework for cities in which energy and climate mitigation measures are addressed in an integrated manner and to explore alternative development pathways for cities.

References


