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Urbanization, increasing wealth, and energy transitions: comparing experiences between the USA, Japan and rapidly developing Asia Pacific economies

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Urbanization, increasing wealth and energy transitions: Comparing experiences between the USA, Japan and rapidly developing Asia Pacific economies

Peter J. Marcotullio♥ and Niels B. Schulz♠

Abstract

This paper explores differences between energy transitions experienced by developed nations (USA and Japan) and those of several rapidly developing economies (China, Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Thailand and Vietnam). We argue that those economies that underwent energy transition before the period of intensive globalization (pre-1970) had significantly different energy transition experiences than those that developed during contemporary times. Specifically, we suggest that due to the *Time-space telescoping* of development, which has accompanied globalization, transitions occur sooner, conditions change more rapidly and challenges emerge more simultaneously now than during in the past. Indeed, transitions between energy supplies and consumption sources are difficult to observe in contemporary developing economies making the notion of transitions questionable. At the same time, total energy supply and consumption at any comparable level of GDP per capita and urbanization level, for most rapidly developing economies are lower than experienced by the USA. This result translates into is lower total carbon emissions when compared across these parameters. We explore these relationships focusing on total primary energy supply and total final energy consumption transitions and comparing the linkages between these transitions and GDP per capita and urbanization levels. These results have implications for both theory and policy.

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1. Introduction

The world's human population is undergoing a transition from being largely rural to urban. By 2008, the global urban population will be, for the first time in global history, greater than 50% (United Nations Population Fund 2007). As such, urban growth and accompanying changes with urbanization are increasingly being recognized as one of the critical development issues of the 21st Century.[1]

Energy use and related issues of poverty, health, carbon emissions, etc are high on popular, international and academic agendas (Arrow 2007; Gore 2006; The Stern Review 2006; United Nations Development Programme 2007). Energy supply and consumption has been linked to a large spectrum of development concerns including sustainable development, industrial development, air and atmosphere pollution and climate change (United Nations 2006a).

With its large population and rapidly rising economic wealth, the Asia Pacific region has become an important environmental focal point for both consumption of resources and generation of emissions at the local, regional and global scales. This region includes several large and growing economies of differing per capita incomes. The region's population is expected to grow 25% over the next 25 years to reach almost 2.5 billion (United Nations 2006b). Predicted economic growth (year-2006 through year-2010) for the Association of Southeast Asian Nations (ASEAN) (5.6–6.5% annually) is higher than that for the world (3.1–3.5%), USA (2.5–3.5%) and Japan (1.2–2.8%). China's forecasted annual growth (6.6–8.6%) is more than double the world average during the same period (The Economist Intelligence Unit 2006). Due largely to rapid economic growth, under business as usual scenarios, energy use in ASEAN and East Asia, will at least double over the next 20-30 years (Aldhous 2005; ASEAN 2002; International Energy Agency (IEA) 2006).

Urbanization requires vast amounts of energy resources and it is estimated that about 75% of global technical energy use is consumed in cities. First, the direct 'running costs' of cities are high for functions like space heat-

[1] Due to this recognition, several international research and academic institutions have begun urbanization research programs and projects including, *inter alia*, the International Human Dimension Programme's (IHDP) Urbanization and Global Environmental Change (UGEC) project, the Global Carbon Project's (GCP) Urban and Regional Carbon Management (URCM) project, the Convention on Biological Diversity's (CBD) Cities and Biodiversity: Achieving the 2010 Biodiversity Target, the United Nations University's (UNU) Sustainable Urban Futures (SUF) Programme, the Alliance for Global Sustainability's (AGS) new forum on New Thinking on Urban Futures, and the Third World Academy of Sciences' (TWAS) Cities, Science and Sustainability project.

ing, air conditioning and lighting in buildings which together account for 40-60% of direct urban energy consumption. Second, transporting goods and services now accounts for 30% global energy consumption, a share that increases with the spatial and functional differentiation of economies and the shift from rural to urban lifestyles (Schurr *et al.* 1979). Third, cities are also centers of indirect energy consumption including most obviously those resources required to produce food and other biomass. With lower percentages of the population engaged in agricultural activities and the need to supply food to larger non-agricultural populations, primary sector activities become more resource and energy intensive (Jones 1991). Further activities with significant costs in terms of indirect energy use include the use of construction materials (like steel, aluminum, glass and concrete) and consumer goods, which require vast energy investments during their production stage elsewhere. Such life cycle costs can be conceptualized as 'embodied energy'.

Interestingly, the systemic relationship between urbanization and energy supply and consumption has been less studied (for exceptions see, Dhakal 2004; Jones 1991; Shen *et al.* 2005). Importantly, there has been a lack of comparative studies on the interaction of urbanization, energy supply and consumption and rising incomes.[2]

One pathway for examining these relationships is to focus on energy transitions. Energy transitions are a change from one state of an energy system to another one, for example, from comparatively low levels of energy use relying on non-commercial, traditional, renewable fuels to high levels of energy use relying on commercial, modern, fossil-based fuels (Gruebler 2004). Energy transitions have been historically documented for the USA (Marchetti 1988; Melosi 1985), but these transitions have been examined over either time or wealth. Comparative studies of this type have demonstrated the differences between energy transitions amongst economies developing at different points in time (Marcotullio & Schulz 2007). We now need to understand better the specific role of urbanization in energy transitions.

What is the relationship between urbanization and energy transitions? Do the relationships that held through the history of the developed world, still hold for currently developing nations? This paper focuses on these questions by comparing energy transitions amongst a select set of nations (USA, Japan, China, Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Thailand and Vietnam) in an attempt to outline energy transitions and identify differences in transition experiences.

[2] Dhakal (2004) provides one of the first comparative studies of urban energy use focusing on Tokyo, Seoul Beijing and Shanghai. As excellent as this study is, the focus is on current differences and not historical trajectories.

The second and next section of the paper presents the perspectives used in the analyses. Thereafter, the third section presents the data sources, the analyses performed and the claims that guide the research. The fourth section compares the urbanization trends between the sample economies. Then in the fifth section, the paper shifts to focus on the results of comparisons of energy transitions over income, time and urbanization levels. In the sixth section we discuss the results and in the seventh section we provide limits and caveats to the findings. In the eighth and last section we conclude with policy recommendations.

2. Background: linkage between development, urbanization and energy transitions

The basis for this study relies on theories related to three important development trends. First, there are theories related to environmental and energy transitions. We apply urban environmental transition theory to energy transitions. Second, we briefly explore the drivers of transitions. We argue that transitions are affected by a number of different factors, both directly and indirectly. Third, we focus on how these drivers have changed over the past century and most intensely over the past few decades. We claim that due to changes in drivers there are time- and space-related effects. These effects shift human-natural interactions and therefore have significant impacts on environmental and energy transitions. We describe the effects and various time-space concepts that provide ways in which to understand the unique circumstances experienced by developing economies today.

1. Urban environmental transition theory

What are the environmental challenges that cities undergo as they develop? Urban environmental transition theory provides a powerful tool for addressing this question (see for example, McGranahan *et al.* 2001; McGranahan & Songsore 1994). Rather than the simple notion described by the environmental Kuznet's curve (EKC) of an 'inverted-U' shaped function relating environmental degradation to rising incomes (see for example, Grossman & Krueger 1995), the urban environmental transition theory identifies layers of changes in the relationship between affluence and urban environmental burdens. The claims are based upon an empirical tendency for urban environmental burdens to be more dispersed and delayed in higher income cities than in lower income cities. In summary, the theory suggests that in poor cities, environmental challenges are localized, immediate and health threatening. In middle-income, rapidly developing cities, environmental burdens are citywide or regional, somewhat more delayed in their impacts and a threat to both health and ecological sustainability. In affluent or high income cities, environmental burdens are global, intergenerational and primarily a threat to sustainability.

The theory includes the addition of geographic and temporal scale to notions of urban sustainability and as such, questions whether urban sustainability has been achieved by any city in the world. Essentially, by including the differences in environmental burdens and the scale at which the impacts are felt, the theory predicts that at different levels of income different problems dominate, but that no city has addressed all issues.

Historical urban research that associates urban growth and environmental impacts suggests that in the past, urban environmental burdens were addressed by simply dispersing the associated harms to greater scales. Urban environmental historians in the USA have also noticed the change in environmental burdens over time. Melosi (2000) identifies how environmental challenges associated with water supply, sanitation and solid waste management have undergone a series of changes over time and have increasingly spread to wider geographical spaces. Tarr (1996) suggests that urban environmental history can be fundamentally characterized as the search for larger and larger sinks in which we have sent wastes. Both these historians have identified changes in type and geographic and temporal aspects of environmental burdens that are comparable to urban environmental transition theory.

Those working in the area of energy have also identified historical transitions at both the macro-level for developed countries (Elias & Victor 2005; Gruebler 1998; Gruebler 2004; Marchetti 1988; Nakicenovic 1988; Smil 1994) and for developing countries at the household level (Elias & Victor 2005; Smith 1987; Victor & Victor 2002). The first transition was associated with the Neolithic revolution and energy technologies that are associated with the shift from hunting and gathering to agriculture (Diamond 1997). It was not until the Industrial revolution that societies turned from biomass and animate power supplemented with wind and water power as supplies to fossil fuels (Gruebler 1998). The Industrial revolution signed a trend of sequential changes in primary energy supplies with increasingly higher energy densities; from coal to petroleum to natural gas and nuclear power). With each change in energy source, came a reorganization of economic activity and new environmental consequences.

Urban environmental transition theory has been applied to different contexts, including economies in rapidly developing Asia (Bai & Imura 2000; Marcotullio & Lee 2003; Webster 1995). These applications have either simply described differences between cities of different income levels or included changes in the speed of transitions. Bai and Imura (2000), for example, insist that environmental transitions can be observed within Asia cities and that they have occurred in sequence, from traditional to industrial, to modern environmental challenges, albeit in a faster manner than previously experienced.

These previous studies miss important aspects of the current development context. That is, they overlook how environmental challenges within rapidly developing countries are emerging at lower levels of income and in a more overlapping or simultaneous fashion (Marcotullio 2005b). At the household level, for example, recent studies identify how within some current developing societies, families have not experienced a regular and consistent path from tradition fuel consumption to the use of electricity and other modern fuels (Barnes *et al.* 2005).

What might be the influences affecting transitions and why would they change over time? Many emphasize the importance of income in influencing transitions (Leach 1992; Pachuari 2004). The authors of the urban environmental transition theory argue that affluence is only one of many factors explaining these shifts.[3] Elias and Victor (2005) suggest that climate, resource endowments, and distance to markets are non-income related aspects that force energy transitions. We argue that there are many more influences on transitions at the macro-level, as will be described in the next section. Unfortunately, as many of these influences were overshadowed by a focus on economic growth, their effects have been largely ignored.

2. Drivers of urban environmental transition change

There are potentially a great number of drivers of change that help to produce the patterns identified in urban environmental transition theory. "Drivers" can include any natural or human-induced factors that cause a change in the environment. Given the large number of factors in urban environmental change, a useful distinction between different types include those that have "direct" (where the impact between the drivers and the impact can be measured) and those that have "indirect" (where the impact between the drivers and the change cannot be measured) influence.

We can see the effect of such different drivers on transitions within cities in the developed world in urban environmental history. For example, to explain the development of the Croton Water Supply system in New York

[3] McGranahan, *et al* (2001) stress that transitions do not reflect human preferences at different levels of economic development. Rather, they suggest that transitions reflect social inequities and the failure to accommodate human preferences, preferences that are not easily represented and negotiated within current socio-economic and political systems.

around 1840-1850s, which enabled the rapid population, economic and physical expansion of the city a range of drivers need be recognized, among them the completion of the Erie Canal, low previous levels of technology adoption in water supply, miasma disease theory, health and fires crises, public interest in wresting control of water supply from the private sector and elite interest in making New York one of the leading cities within the then growing USA. Given the intensity of these drivers, New York City was one of the first to implement a comprehensive water supply system (and even went out of the city to get water supply) (Burrows & Wallace 1999). The centralization of water and the importance of large infrastructure projects associated with water supply became a "path dependent" outcome of development in this arena for many US cities (Melosi 2000). Other cities in the nation soon followed suit, but to their later dismay, made decisions to extract water from nearby water bodies (see for example Philadelphia and Chicago).

This important transition ushered in a new era of environmental change and facilitated the growth of cities in the USA. It was the beginning of the industrial revolution in the country and rapid economic, social and political changes occurred. The rapid increases in water use, the failure of the contemporary drainage system, the threat of disease within an increasingly concentrated population, the ability of the political machine to use public works for rent seeking purposes, among other factors, prompted the development of the sanitation system in New York City around 1870s-1880s. Importantly, the "unintended consequences" of developing a water supply system was an important force in the development of a sewage system. That is, once large amounts of water were brought into the city, a new crisis arose as to how to get the increasingly larger volume of used water out of the city. Hence, across the USA cities sanitation systems were developed after water supply systems (Tarr 1999).

It was not until the turn of the century (a full 50 years after water supply systems were successfully implemented), however, and in adoption of chlorine powder to urban water supplies around the country, that the link between density and disease was broken (Melosi 2000). At that point, urban typhoid fever levels plunged dramatically. That is, the development of water supply and sanitation systems along with advances in germ theory and water treatment technologies that helped cities in the country largely overcome traditional health burdens (Melosi 2000).

Overcoming health burdens allowed cities to further increase in density, which also created massive markets for products. Commercial districts separated from residential areas within cities and the beginnings of a mass market developed, particularly within the metropolitan areas of the country.

Industrial production on a large scale developed within a national economic and with this the beginnings of chemical pollution.

At about this time, another transition was occurring within cities of the developed world. Changes from horse and other animate powered modes of transportation to motor vehicles depended upon the development and the mass production of the technology, increases in average incomes, shifts in housing arrangements and the structure of cities, improvements in street paving, the rise in importance of engineers in city planning, the health impacts of horses and changes in the perceived use of streets, among other influences. Interestingly, health advocates at that time, promoted the automobile at that time as an answer to horse pollution and hence an environmental solution (McShane 1994).[4]

In this perspective, development proceeded through waves that followed linked changes in the economy. This relationship between these drivers and development patterns (whether contingently or structurally linked), created sequential shifts in many transitions (urbanization, demographic, health, nutrition, environmental, energy, etc) in the Western experience. The long waves of economic growth (Kondratieff 1979) focused on economic and technical change, but included a number of other shifts over a 50-60 year period (Berry 1997). Work associating these shifts to patterns of historic growth in European and North American societies concluded that waves of development did exist, but too much emphasis was placed on the potential structural linkages with the economy (Maddison 1991).

We argue that the strength of the structural linkages is as important to current policy thinking, as how conditions were addressed. Historically, in the USA addressing urban environmental issues took on a "first-things-first" methodology (Warner 1955), which had (and continues to have) a strong (and inappropriate) presence in development thinking today. We argue that even if

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[4] The horse, in the late nineteenth century city, rivaled humans in creating waste. In the USA, at the turn of the century, there were 3 million to 3.5 million horses in use. Engineers estimated that a city horse produced more than 20 pounds of manure and several gallons of urine daily, most of which ended up in the streets. Cumulative totals of manure produced by urban horses were staggering. For example, 26,000 horses used in Brooklyn and 12,5000 horse in Milwaukee, yielded about 200 and 133 tons of manure daily, respectively. In the mid-1880s, the discharges of 100,000 horses and mules, pulling 18,000 horse cars over 3,500 miles of track nationwide, cluttered the nations' street, corroded the metal streetcar tracks and also threatened the health of city dwellers. Moreover, since the life expectancy of a city horse was only about two years, carcasses were plentiful and difficult to move. New York City scavengers removed 15,000 dead horses in 1880. Often dead horses lay in the streets for days before they were carted away. It is not surprising therefore, that the automobile was received as an environmental benefit (Melosi 2001; Tarr 1993).

long waves of development did exist and were related to economic structural adjustments, they are very different if not absent today. Indeed, the emergence, timing and speed of environmental conditions have altered. These changes have been due to a shift in the drivers of the past, which together have changed time-space dynamics.

3. Time- and space-related effects and changes in the drivers of change

There has been a large body of literature that suggests the contemporary development context is significantly different from previous eras (see for example, Held *et al.* 1999). Importantly, globalization, defined by the stretching of a number of human relationships over space, is altering the way human activities and perceptions unfold. Globalization and domestic influences, over the past 30-40 years, have had time- and space-related effects.

Time-related effects are changes in development patterns as a result of changing speed and efficiency of human socio-economic activities. Time-related affects draw places closer together and create urban dynamics across the globe forcing convergence among urban areas. That is, they create similar conditions across cities of different social, cultural and political histories and economic levels. Space-related effects concentrate increasingly diverse phenomena unevenly in spatial nodes (i.e., within and among cities) and create urban dynamics across the globe forcing divergence among urban areas. Space-effects increase differences among cities, concentrating what was once unique across an entire nation, into its cities. Massey (1996), for example, has pointed out how different and diverse phenomena are increasingly concentrated in cities.

There is a significant history of studies of time-space effects. Within the literature, there are three interlinked ways of thinking about how these effects relate including: *time-space convergence*, *time-space distanciation* and *time-space compression*. *Time-space convergence* refers to the decrease in the friction of distance between places. It refers to the apparent convergence of settlements linked by transport technology. As transport evolved travel time would be reduced between them, giving the sensation that they had moved closer together. The velocity at which settlements are moving together may be called the time-space convergence rate (Janelle 1968, 1969). This notion is often expressed as the "world is an increasingly small place."

Time-space distanciation refers to the stretching of social systems and relationships across space and time. The argument is that people interact in two ways: face to face, and remotely through transport and communications technologies. The first way of interaction is more occurring between people living in different nations, more frequently, due to air travel. The second modality has become increasingly important with globalization, "distanciating" social relationships. Together, during the contemporary period, it is not necessary for people to be physical present at a particular location to be important social actors, as these relationships have been stretched over space (Giddens 1990).

Time-space compression refers to "the annihilation of space through time" that lies at the core of the capitalist dynamic (Harvey 1989). While the concepts of *time-space convergence* and *time-space distanciation* do not offer an explanation for why social relations and development patterns have been stretched across space and subsequently dramatically changed the development context, *time-space compression* does. The argument is that this is one of the central processes of capitalist development. As "time is money" the tendency for relations under this mode of production is to find ways to speed up the "circuits of capital" so as to reduce the "turnover time of capital" (i.e., the amount of time it takes to convert investment into a profit). As a result, technologies and policies to facilitate these processes facilitate *time-space compression*. The effect of time-space compression is disorienting and disruptive on both the balance of class power, as well as upon social and cultural life.

This concept encompasses the descriptive accounts of *time-space convergence* and *distanciation*, making them a result of *time-space compression*. Ultimately the argument places an economic rationale at the core of change and not surprisingly, this has been criticized by cultural scholars (Murray 2006).

To these three concepts of time- and space-effect, we add a fourth, *time-space telescoping*. *Time-space telescoping* is also a descriptive narrative similar to *time-space convergence* and *time-space distanciation*. It is evident in the shifting patterns associated with development, such as environmental transitions, such that contemporary conditions and transitions occur *sooner* (at lower levels of income) change *faster* (over time) and emerge *more simultaneously* (as sets of challenges) than had previously been experienced by the now developed world (Marcotullio 2005b). Moreover, there are a number of different direct and indirect influences, including global economic, demographic and institutional shifts as well as local land use and policy influences that have helped to create these trends (Marcotullio 2005a), so it is theoretically different from *time-space compression*.

The notion of *time-space telescoping* stresses that the result of these changes in drivers are more than the speeding up development. China, for example, is not simply undergoing a quicker version of what the UK or the USA had experienced during the late nineteenth and early twentieth centuries. Rather, while speed is important the addition of conditions and challenges appearing at lower levels of income and the layering of previous sequential development patterns makes the current context much more complex and bewildering.

Surprisingly, despite the diversity, complexity and rapidity of change, some of the conditions in the now developing world (i.e., those related to energy consumption) are more efficient or less environmentally harmful than those experienced by the developed world, as measured in a number of ways (i.e., supply and consumption of energy per capita). [5] That is not to say that these conditions are *good* or *good enough*, but rather they are indeed significantly better than experienced in the past. Moreover, when examining the environmental impact of urban activities, at least in terms of energy consumption and related CO_2 emissions, for many developing countries, the rapidly developing world is growing in a much less environmentally harmful manner. These are the notions that this study examines.

3. Data and analysis

Our analyses incorporate several types of data from different sources including: (1) historic energy supplies in the USA (1850-2001) and historic energy consumption data in the USA (1900-2001); (2) recent (1960-2000) energy supply and consumption data in developing and other countries; (3) per capita income (Geary- Khamis international dollars) for all countries analyzed; (4) historic percent GDP originating in the industrial sector for the USA (1900-1997); (5) recent (1960-2000) percent GDP created by the industrial sector for developing and other countries; (6) historic urbanization levels for all economies (from 1850 to 2001 for the USA and 1950 to 2000 for all other economies; and, (7) historical data on CO_2 emissions due to technical energy consumption and concrete production for the periods mentioned above. A detailed description of these data, the sources and limitations can be found in a previous study conducted by the authors (Marcotullio & Schulz 2007).

The analysis requires connecting energy supply and consumption estimates from time series (i.e., indexed by calendar year) to economic growth (i.e., indexed by constant-dollar per capita GDP) and urbanization levels (as percent of total). Maddison (2001) provides Gross Domestic Product (GDP) over time, at Purchasing Power Parity (PPP). The UN (1999; 2006b) provided

[5] In terms of health issues, during the 1990s there was discussion of the double burden of disease, as developing country residents were often exposed to both traditional and modern risks. That is, the concern was that given new combined risks, health in developing countries would decline. Despite the emergence of these new risks, however, longevity and other health indicators have continue to improve.

the urbanization levels for most countries.[6] The International Energy Agency provides data on energy supply and consumption (International Energy Agency (IEA) 2002a, 2002b). US historical census data provide urbanization levels for the USA, which were also matched to UN data, after 1950 (U.S. Bureau of the Census 1975). **Table 1** presents the ranges for the different variables for each country in the analysis.

Using the Geary-Khamis dataset, the USA per capita income was ~ $1,800 in 1850, ~ $4,100 in 1900, ~$10,000 in 1950 and ~$28,000 in 2000. The analyses for hypothesis 2, *faster*, was restricted to countries with a minimum current income of more than $1,800 for energy supply and $4,100 for energy consumption, because of the necessity of making valid comparisons with the USA's experiences. **Table 2a** presents the comparative income ranges for each country with the USA and related total primary energy supply (TPES) and total final consumption (TFC) range figures.,

Similarly, we match urbanization levels between countries. In 1850, the USA was ~ 15% urban. In 1900, the country was ~ 40% urban. In 1950, the nation was ~ 64% urban and in 2000, it was ~ 72% urban. Using urbanization ranges allows for comparisons between different countries and the USA experiences than at similar income ranges. For example, while the Philippines' GDP per capita data didn't allow for a comparison with the USA, similar urbanization levels between economies did. Moreover, given that two economies were "city-states" (Singapore and Hong Kong) for much of their history, we excluded them from comparisons over similar urbanization levels. **Table 2b** shows the comparative income ranges for each country with the USA, over similar urbanization levels, and the associated TPES and TFC range figures.

We use a variety of different, but straight forward analyses to examine the differences in trends between economies, both in terms of GDP per capita and urbanization levels. We examine the sooner hypothesis by identifying whether the nations in our database experience supplies in the more advanced carriers or the consumption of more advanced energy technologies at lower economic growth and urbanization levels than those of the USA. More advanced carriers include all those in the database except biomass and coal. We use a binary test, recording whether or not there were significant levels of supply or consumption of these flows at income levels under those of the USA. The significant level was arbitrarily identified as 0.01 tonnes oil equivalent per capita (10 kg oil equivalent per capita) per year.

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[6] The UN provides historical urbanization level data for most countries starting from 1950 for 5 year intervals. Annual levels were calculated by estimating 5 year annual average increases.

To examine whether changes occurred faster for those economies developing under intensive globalization forces, we compare rates of change (over time) in energy supply and consumption using the beta values of the ordinary least squares analysis. These slopes provide an indicator of rate of change. We make all comparisons at similar income ranges between individual countries and the USA in order to adequately compare levels of economic income. We also examine rates of change under similar urbanization ranges and over changes in percent urbanization level.

To examine whether the transition sequence is experienced in a similar manner across economies, we first identify the transitions that the USA underwent during its development. We equate energy transitions with those periods when one carrier's numerical share of total energy supply surpasses another. We then identify the income and urbanization levels, at which these transitions occurred and the amount of time and percentage urban share change between transitions.

USA transitions in the supply of energy (**Figure 1**) over time demonstrate the sequential nature similar to the global experience (Grubler and Nakicenovic 1996). Before 1850, wood (biomass) held the largest share of energy use among carriers, accounting for approximately 82% of all energy consumption in the USA. In the early 1880s, coal took the lead in total share. Use of coal reached its relative peak around 1910 when it absorbed approximately 80% of total share of energy supply. Oil and gas reached a 1% share of the market around the 1860s and over came coal around 1946. According to these data oil and gas reached a peak market share around 1978, when together they accounted for 78% of the total world energy use. Subsequently oil and gas energy use dropped, but only slightly (to around 64% share in 2000). This slight drop is due to the relative increase in natural gas use while oil supplies fell. In 1973, nuclear power came on the scene with over a 1% share. Nuclear surpassed biomass in 1974. By 2001, nuclear power made up less than 9% and modern renewable sources made up less than 0.5% of the nation's total energy supplies. Since 1973, the relative contribution of coal to the overall TPES of the US has been increasing in response to the first oil crises. Since then it rose from about 16% of TPES to 23% in 1985 where it remains today. It is currently used as the primary energy source for about half of the electricity generated in the US. Despite this small diversion, the smoothness of energy transitions in the US provides a common understanding of how energy transitions evolved over time.

To examine and compare the total amount of energy consumed during similar levels of economic growth and urbanization, we simply summed energy consumed within energy product categories. We also matched the energy consumed within the industrial sectors of each economy and calculated an intensity figure (energy consumed per $) and compared these figures over similar GDP per capita levels. We deem the more efficient industries as those with the lower ratio at a given GDP level (i.e., lower numerical value for industrial energy intensity).

Finally, for we compare the production of CO_2 emissions, as tons of carbon, over similar economic growth periods and over similar urbanization levels. As in the previous analysis, those economies that had overall lower levels of CO_2 emissions are considered to have lower global systemic environmental impact.

4. Comparison of urbanization trends: USA, Japan and rapidly developing Asia Pacific economies

Typically, when discussing urbanization in the Asia Pacific, demographers and urban geographers emphasize the current scale of urbanization and growth of large cities in the region (see for example, Douglass 1998; Douglass 2000; Lo & Marcotullio 2000; Lo & Yeung 1996; United Nations Population Fund 2007). During the first half of twentieth century, when the now developed world was rapidly urbanizing, populations increased from 300 to 400 million in all of Europe (a 0.7% growth rate)[7] and from 90 to 170 million in the USA (a 1.2% annual average growth rate). Compare these population sizes to those of contemporary developing Asia Pacific, with China in the lead (approximately 1.3 billion), followed by Indonesia (approximately 215 million), Philippines (approximately 85 million), Vietnam (approximately 82 million) and Thailand (approximately 65 million). Each of these economy's populations, between 1970 and 2000, have grown at over 1.4% annually, and some have experienced population growth exceeding 2.0% annually (Indonesia and Vietnam).

Within the region, since the 1980s, massive populations have moved into cities. From 1980 to 2005 approximately 335 million people were added to Chinese cities and in Indonesia, during this same 25 year period, 74 million addition people were added to the nation's urban areas. Indeed, Eastern and Southeast Asia experienced a growth of 375 and 152 million people, in their respective region's cities during this period (United Nations 2006b).

The swelling of the urban population has resulted in the rise of large and mega-cities. In 1980, in China for example, there were approximately 42 cities of larger than 1 million and no city in the country was larger than 10 million. By 2005, there were approximately 95 cities larger than 1 million and 2

[7] Europe's average annual rates of population increase were highest between 1800-1900, as many countries in this part of the world were the first industrializers. During this period growth rates reached 1.0%.

were in the mega-city category (Shanghai and Beijing). Within the region, in 1980, there were approximately 67 cities of larger than 1 million and 1 (Tokyo) larger than 10 million. By 2005, there were 131 cities of larger than 1 million and 6 (Tokyo, Shanghai, Jakarta, Osaka-Kobe, Beijing and Manila) larger than 10 million (United Nations 2006b).

McGee (2007) has suggested that these large urban areas continue to grow and are the force behind the growth of many small and medium sized cities that are located close by or sometimes within the urban field of the mega-cities.[8] These mega-urban regions are new and are now and will continue to be part of the urban landscape in the region.

Certainly, the scale of urbanization and the size of urban centers are important considerations in explaining differences between the Western experience and what those of the developing world are currently undergoing. At the same time, however, there are indications of other differences, not as often discussed, which are nevertheless significant. These include the timing and speed of urbanization.

By timing, we refer to the economic income level at which urbanization levels change. What is often missed in the contemporary literature is that urbanization in many parts of the world is occurring at lower levels of economic income than in the past (**Figure 2**). That is to say, that at any particular GDP per capita level, most countries within the Asia Pacific region are at higher levels of urbanization than was the USA. One important exception is Thailand, whose urbanization and economic development patterns are particularly unique in that the country has increased its wealth, but not urbanized in proportion. This may be due to the unique primacy of Bangkok within the urban system of the country and the lower appeal of other major urban centers in the country (Muscat 1994).

The other factor of importance is the speed in which urbanization is occurring. The differences in speed can be seen at the national level and in terms of individual city growth rates. **Table 3** compares urbanization rates, measured in terms of increases in percent urban levels over time, of the USA and several Asia Pacific economies, at similar levels of economic development. In each case, except for Thailand, urbanization levels increased at faster rates than it did for the USA.

We can see further evidence of the rapid speed of urbanization in the region by comparing the experiences Japan, South Korea and the USA. The

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[8] An opposite view is that mega-cities are not growing, but that the medium and smaller size cities in the world are the faster urban growth zones (United Nations Population Fund 2007). McGee's argument suggests that we need to look beyond political boundaries and if done so, will find that most of the so-called rapidly developing cities are in the economic and social orbit of the mega-cities.

USA was approximately 37% urban in 1895 and by 2000 reached 77% urban. This means the nation experienced an increase in its urbanization level by 40% in more than 100 years. Japan was approximately 38% urban in 1940 and by 2000 it reached 78% urban. This country increased the urban share of the population also by 40%, but experienced this change over a 60 year period. South Korea, on the other hand, was approximately 42% urban in 1950 and by 2000 it was 81% urban. This economy experienced an increase its urbanization level of approximately 40%, but did so within 50 years or half the time experienced by those in the USA.

Moreover, differences in speed of urban change can also been seen in terms of individual city growth rates. Within the USA, New York City, one of the fastest growing cities during the nation's industrial development, grew from 200,000 residents in 1830 to more than 1 million in 1860, reaching almost 7 million in the late 1920s when immigration constraints came into effect. During one day at the height of an immigrant wave in 1907, approximately 12,000 people cued up on Ellis Island for entry in the US and during that year 1.2 million people were received in New York (Muller 1993). Manhattan Island reached 2.3 million people by 1910 and according to Ken Jackson, noted New York City historian, by that time had obtained residential densities higher than any city in the world to that point, and possibly since then. Urban growth in parts of the Asia Pacific has been even more spectacular. For example, around 1980, Shenzhen, China, had a population of approximately 350,000. Today, the city's population has reached 8 million, translating into a 12.3% annual population growth rate for 27 years.

These differences in timing and speeds of urbanization associate with significant differences in the urban energy transitions experienced by Asia Pacific economies and those of the USA. We review the comparisons of aspects of these transitions in the next section.

5. Comparisons of the energy transitions: USA, Japan and rapidly developing Asian economies

In this section, we present the results of analyses between urbanization, energy supply and consumption and income trends. We find support for the expected differences in relationships between these variables for rapidly developing economies and those of the USA. Most in the developing world demonstrate sooner urbanization (see above) and sooner use of energy carriers and consumption trends. Moreover, when comparing changes of energy consumption over time, most experience faster growth rates than those of the USA, when compared at similar ranges of income. Furthermore, the linear and sequential transitions experienced by the USA are not evident in rapidly developing Asia Pacific economies. At the same time, it also appears that not all economies experience sooner development of energy carriers by urbanization level. In terms of speed of change over urbanization share, supply and consumption levels are typically lower in Asia Pacific economies than over similar urbanization ranges of the USA. Despite all these seemingly more chaotic circumstances, developing economies are growing in wealth and urbanization with more efficient energy supply and consumption patterns than those of the USA. These more efficient patters have lead to less global systemic environmental impact. The general trends are explored in more detail below.

5.1 Sooner

The evidence for the sooner trend can be seen in both the analysis for energy supply and consumption. We find that for Japan and the rapidly developing economies in the Asia Pacific, many of the carriers appear sooner on the income scale than that of the USA (**Table 4**).

For crude oil and petrol, 7 of the 10 nations in Asia experienced significant supply levels at income levels below that of the USA. Those that did not (including Singapore, Hong Kong and Japan), may have, but the data do not go back far enough to identify the point of emergence. The patterns for natural gas are slightly different. In terms of the emergence of this carrier 5 of the 9 economies from the region experienced significant supply levels at income below that of the USA. In this case, those that experienced the emergence of this carrier at equal or higher levels of income include South Korea, Singapore and Hong Kong. The comparison for Japan and the USA are inconclusive.

For hydro power, the results suggest that 2 of the 6 economies that have experienced the emergence of this carrier did so at lower levels of income than that of the USA. Those that did not follow this pattern include South Korea, Thailand and Malaysia. Data for Japan do not go back far enough to draw conclusions.

For nuclear and modern renewable supplies, most of the economies that are using these technologies do so at sometimes much lower levels of income than the USA. For example, South Korea experienced the emergence of nuclear power at approximately $4,000 GDP per capita while the technology emerged in the USA at approximately $14,300. Vietnam has been deploying modern renewable energy supplies at approximately $2,300 per capita while they first emerged in the USA at approximately $18,500 GDP per capita. The exception to this rule is renewable energy supplies in Singapore, where they have appeared at approximately $20,000 per capita.

The comparisons of the emergence of carriers by levels of urbanization reveal different patterns. Here there are, at least, three categories of differences. First, there are economies, which consistently applied energy carriers at lower levels of urbanization than the USA. For example, China, Thailand and Vietnam all experienced the emergence of crude oil and petrol, natural gas, and hydro power at lower levels of urbanization than that of the USA. Indonesia also experienced the emergence of crude oil and petrol and modern renewable sources at lower levels of urbanization than the USA, but had urbanized to a slightly higher level when natural gas emerged (34.5% in Indonesia compared to 31.5% in the USA). The second group includes those that experienced the emergence of these carriers at higher levels of urbanization. For example, South Korea and Malaysia experienced natural gas at higher levels of urbanization and South Korea experienced the emergence of hydro power at higher levels of urbanization than that of the USA. Japan experienced the emergence of modern renewable sources at higher levels of urbanization, but experienced the emergence of nuclear power at approximately the same level of urbanization (71.2% for Japan, as compared to 72.5% for the USA). The third group includes the "city-states" (Singapore and Hong Kong) which are mostly urbanized and therefore experienced the emergence of carriers at higher levels of urbanization.

In terms of consumption, we compared the emergence of electricity, using the same 0.01 toe per capita level for significance **(Table 5)**. In this case, 8 of the 10 economies experience significant consumption levels at income levels lower than those of the USA. The two economies that did not, Singapore and Hong Kong, were both cities. Japan also experienced sooner consumption of significant electricity energy consumption than did the USA.

The comparison of electricity consumption by urbanization level also suggests three different categories of differences. China, Thailand, Malaysia, Indonesia, Vietnam and the Philippines experienced electricity consumption at lower levels of urbanization than the USA. South Korea and Japan had equal or higher levels of urban population shares when they experienced the emergence of electricity at an important energy carrier. Hong Kong and Singapore were both under much higher levels of urbanization for the same comparison.

5.2 Faster

There are several ways to compare urbanization, income and changes in energy supply and consumption. We choose two representative comparisons. First, we compare the change in energy supplies over time at similar levels of income. Second, we compare the change in energy supply over urbanization levels at similar levels of urbanization. The first comparison tells us something about how quickly energy supplies and consumption changed over time during similar economic growth ranges. The second comparison tells us something about how quickly energy supplies and consumption changed over urbanization levels during similar urbanization ranges.

The results for these comparisons for total primary energy supply and total final consumption are presented in **Table 6** (a and b) and **Table 7** (a and b). In terms of changes in total supply over time at similar GDP per capita income ranges, 8 of the 10 Asia Pacific economies experienced faster rates of change than that of the USA. Exceptions include Thailand (which underwent nearly the same TPES increases as that of the USA) and Hong Kong (which underwent slower TPES increases than that of the USA). In terms of comparison of changes in total final consumption, all 6 comparisons yielded faster growth in Asia Pacific economies than that of the USA.

In comparison, however, the reverse is typically true for changes in TPES and TFC over similar urbanization levels. For example, for energy supplies, 2 of the four comparable economies grew faster than that of the USA (China and Thailand). China's supplies grew at slightly faster rates (27.3 koe/capita for every percent increase in urban population) than that of the USA (25.6 koe/capita for every percent increase in urban population). For Thailand, similar urbanization ranges for the USA produced negative change in supply of energy. Upon closer examination, the USA comparative period with the Philippines includes a period of turmoil leading to and including the US civil war, during which time total energy supply decreased.

For consumption comparisons over urbanization levels, changes in Malaysia and Japan were faster than those of the USA. In the other 2 cases, changes in consumption levels in the USA outpaced those of South Korea and the Philippines.

To examine these differences in more detail we break down supply and consumption changes into carriers, products and sectors. For example, to explore differences in total energy supply we first look at changes by carrier (**Table 8**). Within those that experienced faster increases in energy supplies, typically crude oil, petrol and natural gas were the fastest growing carriers. For these economies, the rapid expansion of petrol, oil and natural gas outstripped growth in the USA. For South Korea, Hong Kong and Japan the increases in coal supplies were also important. Moreover, for South Korea and Japan faster increases in nuclear power energy sources were also greater than those of the USA. For the Philippines similar economic growth periods for the USA produced negative change in supply of energy. Like comparisons at similar urbanization with Thailand, the USA period for this comparison includes the US civil war. This may be regarded as part of historical contingency rather than a structural pattern.

When we compare the details of changes in energy supply carriers over changes in urbanization we find interesting differences amongst Asia Pacific economies in comparison to the USA experience. For example, petrol, oil and natural gas increases in Asia economies were lower per increase in urbanization level than that of the USA, except for Thailand, Malaysia and Indonesia, meaning that for these economies during similar urbanization levels, they experienced faster growth in these carriers when compared to the USA. For coal, South Korea growth was faster per level of urbanization than that of the USA. For all other categories in these comparisons, except for the growth of modern renewable sources in the Philippines, changes occurred faster in the USA.

Increases in electricity consumption followed basically similar patterns as the total energy consumption (**Table 9**). In all cases, growth in electricity consumption was equal to or greater than that of the USA under similar GDP per capita income ranges. For electricity consumption per percent urbanization level, growth was faster in Malaysia and Japan than that of the USA, but slower in South Korea and the Philippines.

Exploring changes in energy consumption by sector provides further insights into differences (**Table 10**). Over time, during similar GDP per capita ranges, changes in energy consumption in the industrial and transport sectors in Asia Pacific economies were typically faster than that of the USA. For speed of change in industrial sector consumption, Hong Kong and Japan experienced slower rates of increase than that of the USA. The commercial sector's energy consumption in South Korea, Thailand, Malaysia and Japan grew at faster rates than that of the USA. In no case, did an Asia Pacific economy experience faster energy growth in the residential sector when compared to the experiences of the USA.

Over urbanization ranges, we find that growth in industrial energy consumption is greater per level of urbanization than that of the USA for three of the four Asia Pacific economies (South Korea, Malaysia and Japan) that could be compared. Interestingly, however, energy consumption is greater per level of urbanization in the commercial sector for Malaysia and the Philippines than that of the USA. Furthermore, in Malaysia, transport energy consumption grew at a greater rate per level of urbanization than that of the USA. The largest differences in energy consumption levels were in the residential sector where in all cases increases in the USA were much higher than for those in the Asia Pacific economies.

5.3 More simultaneously

The more simultaneous trend can be partially demonstrated through a comparison of the timing of transitions (**Table 11**). Importantly, the table demonstrates that the USA sequential pattern of transition from one energy form to another did not occur in the other economies. That is, for none of the economies study, were there a similar pattern evident as the sequencing experienced by the USA (i.e., many transitions occurred out of order for developing economies when compared against the USA and global standard). For example, Indonesia has yet to experience a biomass to coal transition, but have already experienced a biomass to oil and natural gas transition. Also many countries had experienced some transitions before the database started, but have a history of transitions that occur to be falling out of timing with those of the USA.

When transitions did occur, they often were at lower income and urbanization levels than that of the USA. For example, the transition from biomass to liquid and gaseous fossil fuels took place in China in 1997 when the nation stood at 30.6% urban and had a GDP per capita of $2,973. The same transition occurred in Thailand in 1980 when the nation was at 17% urban and had a GDP per capita of $2,554. In Indonesia, this transition occurred in 1989, when the economy stood at 29.5% urban and had a GDP per capita of $2,352. In the USA, this transition occurred in 1916, when the nation was at 48.9% urban and had a GDP per capita of $5,459.

5.4 More efficiently

We compared the total consumption of energy across sectors for similar ranges of income and urbanization levels as well as the measured differences in industrial output per energy input and found in both cases that most economies were able to develop in a more efficient energetic manner when compared to that of the USA.

Table 12 presents the comparative total energy consumption by carrier for the developing countries and the USA and Japan summed over similar economic growth and urbanization ranges. In all cases, the supply of energy was much (sometime over 10 times) greater per capita in the USA than in the developing country. For example, during the economic growth of South Korea, the average South Korean was supplied with 34 tonnes of oil equivalent worth of energy. For the same economic growth range the average American was supplied 267 tonnes of oil equivalent worth of energy.

We find the same differences when comparing total energy consumption over similar urbanization levels. For example, to move the country through similar levels of urbanization, the average South Korean consumed 24.1 tonnes of oil equivalents while the average American consumed 446.1 tonnes of oil equivalents.

The comparison of energy consumption in the industrial sector per GDP generated in the industrial sector **(Figure 3)** obviates the fact that developing countries have used less energy per industrial GDP value than that of the USA at any level of comparable economic growth. As these figures are aggregates of all industries, however, care must be taken in making specific evaluations.

5.5 With lower systemic global environmental impact

Finally, we compared the total carbon dioxide emissions from each economy to those of the USA over similar levels of economic growth and urbanization levels (**Figures 4 and 5**). These data were not calculated using the energy data appearing in our charts and tables, but rather were collected from a different source. They include total carbon dioxide emissions from technical fuel use and cement production, but not all societal activities [9] and are expressed in units of tons of carbon[10]. The data represent a proxy for the total carbon emissions and therefore systemic global environmental impact.

The graphs demonstrate that for all levels of income and for almost all levels of urbanization, the USA has produced more carbon emissions per capita than any other economy or group of economies in the database. Singapore comes close to USA levels, but consistently emits lower levels of carbon.[11] In terms of emissions by urbanization level, it is interesting to note that Thailand is producing more emissions per level of urbanization than that of the USA.

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[9] These data do not include, for example, carbon dioxide released due to landcover change and other agricultural activities.

[10] To convert tons of carbon to tons of carbon dioxide multiply by 3.667.

[11] The CO2 emission data from Marland et. al include those emissions of bunker fuel for international freight shipping and aviation, which contribute to more than 50% of Singapore's emissions in 2000 (Schulz 2006). While this procedure is justified from the view of total emission accounting it differs from the national responsibility according to IPCC guidelines, which excludes such emissions from the national liability. Furthermore a large share of Singapore's emissions originating in its refining industry and caused by fuel which is subsequently exported and consumed elsewhere. Such life cycle effects due to locations of the petrochemical industry are inflating per capita consumption in Singapore while they deflate the apparent emissions in the country of actual fuel combustion.

6. Discussion

Why are some economies experiencing the emergence of energy carriers and consumption patterns at lower levels of income than the developed world and specifically than the USA? There are, of course, many different reasons for this outcome. Certainly, technological advances are important. Simply, when now developed world economies were in their developing phase, many of our current technologies (such as automobiles, cell phones or the internet) were not yet innovated. Hence, the developing world is benefiting from the technological development and improvements, for example, of electricity and modern energy conversion techniques[12]. These originated in different parts of the world and variations in trade and exchange of information and technology should explain some variations in the diffusion of usage. We expect that those economies that are more open are experiencing a sooner emergence of some energy use categories than those that are not.

Moreover geographic variations in resource endowments should be a similarly important factor. Most countries for example do not own large oil reserves or water power resources. As they have to buy energy resources on the global market they will choose the most advanced and flexible technology.

Guaranteeing security of energy supplies on the other hand might be paramount for purely economical considerations in adoption of energy technologies. Countries might, for example, stick to coal as a source of electricity production because of its domestic availability and despite the fact that gas powered powerhouses would allow more flexible and efficient sources of electricity generation. Also the adoption of nuclear energy technology can be more related to international geostrategic positioning of a country and a question of prestige then being driven by purely technological or economic considerations.

There are positive aspects of sooner adoption of energy technologies. Adopting certain carriers can lead to efficiency gains on the part of the economy as well as social benefits. In some cases, scholars have claimed that by using modern technologies at lower levels of income, the developing world can by-pass problems experienced by the now developed world (i.e., "leap-frog" over challenges). This notion suggests that developing countries have the opportunity to "do it right the first time" by installing clean efficient technology,

[12] In the early phase of the US industrial development for example relatively inefficient steam engines were the main provider of mechanical energy. Currently developing countries can choose to install either internal combustion engines, electric motors or stearling engines to provide similar energy services.

among other changes (Goldemberg 1998; Ho 2005). This is confirmed by studies that have identified trends of increasing energy efficiency experienced by developing "late comers" (Smith 1993). The advantages of some of these technologies, the importance of electricity for example, in terms of both health and social advances cannot be underestimated (Nye 2001).

In other studies, there is evidence that globalization and foreign direct investment (drivers associated with globalization) have facilitated some "leaf-frogging" in the energy area (Meilnik & Goldemberg 2002).[13] In the developing Asia Pacific, there is also some evidence that industries are implementing cleaner production technologies and processes in industry (see for example, Angel & Rock 2000). In terms of our analyses we catch some of these differences when comparing the experiences of Malaysia, Thailand and China, which are open economies, to those of Japan and South Korea, which have keep trade and foreign direct investment inward flows lower. The former typically experienced sooner development of carriers, while the later had differential results.

Others suggest leap-frogging is dependent upon a host of legal, political and institutional frameworks (Ho 2005). Therefore establishing appropriate conditions for leap-frogging requires a host of abilities including institutional capacity. Certainly, governments in the region have been eager to develop their energy supplies and spread them beyond urban areas, so policy plays a role also.

Moreover, rapid social acceptance of the technology, in terms of the use of various technologies is also an important factor, among many others, that plays a role in the sooner aspect of current development patterns.

Why then would some economies not experience the sooner aspect of time-space telescoping? Besides the openness to globalization, in the energy arena, there is also the importance of natural endowments in energy transitions. Sachs and Warner (1995) provide an analysis of how during the post-war era, the economic performance of resource-rich countries was weaker than resource-poor economies. Following Matsuyama (1992) they argue that land-intensive economies with open economies will promote agriculture rather than manufacturing. The move away from manufacturing results in shrinkage in the sector (the Dutch disease) and slower growth. This situation is currently happening in African countries due to increasingly heavy inflows

[13] The rapid diffusion of information technologies such as mobile phones is an example of how current technology can be provided by private companies, often under competitive conditions,. Mobile phones bypass the large investments needed by traditional copper wire telephone networks.

of Chinese investments in primary industries; mining, agricultural and oil (The Economist 2006).

In our study, however, we did not find this to be true. Those economies that did not experience the sooner development of energy carriers were either city-states (such as Singapore and Hong Kong), which by definition have low resources, or have low levels of the resources. For example, in terms of natural gas and hydro power, South Korea developed these technologies at higher levels of income as compared to the USA (both of which are in low quantities within South Korea). This suggests that the availability, domestically, of the energy supply will play an important role in when the economy can begin to develop it as an important carrier. Alternatively, in the case of hydro development in Thailand, the country has large resources, but has met with political opposition against new large hydropower plans and therefore production has been slow (Todoc *et al.* 2007). In this case, it may have been political influences that helped to bring out results. At the same time, however, in the cases of Singapore, Hong Kong and South Korea, these economies focused on developing industrial power rapidly and concentrated on the most modern carriers despite the fact that they have low domestic resources (fossil fuels and in the case of South Korea, nuclear power).

In terms of the timing of significant electricity consumption, only Singapore and Hong Kong were economies that may have developed supplies after those of the USA (and in each case data are not available to fully compare differences). At the same time, no other economy experienced significant consumption levels at income levels higher than those of the USA during its initial electricity consumption periods. This makes sense as the increasing electricity and modern energy consumption is part of current development planning.

What does is mean when economies develop energy carriers and consume modern supplies at lower levels of urbanization than that of the USA? There are, at least, two possible explanations for this finding. First, the use of these carriers or consumption patterns could be due to more intensive per capita use and consumption in Asia Pacific cities than those of the USA or that the use of the carriers and consumption patterns is more widespread (including rural areas) than experienced by the USA. Both notions suggest that urbanization is occurring under different energy conditions. In the past, the developed world's urban growth was significantly altered with changes in and quality of energy sources and consumption patterns. If energy carriers are appearing at lower levels of urbanization, these will arguable place different pressures on urban growth and urban patterns. If, what is occurring is the spread of energy supply and use beyond urban areas and therefore lowering the urbanization levels at which significance supply and consumption appears, then it translates into significant advances in rural use. This is seen is some of the countries within the region. For example, Vietnam reported that by the end of 2004, the national power grid reached 900 poor communes. All districts and 90% of communes through the country have electricity (United Nations Development Programme 2007).[14] At the same level of income and urbanization, however, the USA could not boast this claim.

Those economies that did not experience this phenomenon include city-states (for obvious reasons) and South Korea and Malaysia for some of the energy carriers. In the later cases, the results suggest that urbanization may not be proceeding in a more efficient manner than that of the USA, but as economic growth is so rapid, it is overwhelming other patterns. That is, the use of higher quality energy supplies has come later in the urbanization process, but earlier in the wealth generation process. As such, given that different energy sources create different pressures for urban development, we would expect that these economies will not only face different pressures than did the USA, but also face different circumstances than their neighbors.

The results of the faster increases in supply and consumption, particularly for the rapid developers, are not surprising. Energy use and economic development are linked (at least for the initial periods of growth). As countries grow, they use more energy to help organize more complex activities. Faster up-take of energy, however, also comes with increased complexity of management. Rapidly developing countries therefore need to build and manage complex energy systems faster than previously demanded.

Given the rapidity of change, the question whether these economies are keeping up with energy infrastructure demand is questionable and if not, what impacts this has on energy supply and consumption is not well understood. Studies in rapidly developing Asia suggest that infrastructure development is not keeping up with the demands creating through economic growth (Brockman & Williams 1996). Furthermore, given rapid economic growth, trends in environmental impact from lack of infrastructure may lag. For example, a recent study suggests that there is a different relationship between provision of road infrastructure and road transportation fuel consumption and consequent carbon dioxide emissions in developing Pacific Asian economies than in the USA. Essentially, adding kilometers of paved road in rapidly developing Asia countries results in much greater increases in road transportation fuel consumption than it did in the USA. As Asia Pacific economic growth

[14] This is certainly not true for all countries in the region. In Cambodia, for example, over 92% of the population is dependent on fuel wood as its primary energy source. Rural areas rely almost exclusively on wood for their energy needs (United Nations Development Programme 2007).

slows and infrastructure catches up with demand (i.e., overcomes the so called, "infrastructure bottleneck"), levels of global emissions from rapidly developing countries may approach patterns set by developed countries including those of the USA (Marcotullio & Williams 2007).

When comparing transition experiences the findings suggest that energy transitions no longer exist for developing countries. That is, the sequential patterns of development, in terms of energy use, are not observable in our sample. Those in the USA have long believed that changes made in supply, from one major source to another, as an obvious improvement – more, better and cheaper energy. Thus, it has been generally accepted that the United States witnessed major shifts in energy sources: from wood and waterpower to coal (or from renewable to nonrenewable sources) in the mid-nineteenth century; and form coal to petroleum and natural gas in the early twentieth century. Because of these perceptions, scholars have argued that a "single-source mentality" developed (Melosi 1985, p. 9). Hence, energy sources have been regarded as competitive rather than complementary meaning that there was "one best way" that prevailed over each energy era.

For the rapidly developing world, complementarity is more often experienced than competitiveness among supplies, as the findings suggest several different carriers are used simultaneously and that transitions do not follow sequential patterns. Certainly, the slow transition from one energy source to another is not distinguishable. Energy mixes may not be due to energy source scarcity or quality, but due to price, technology, transportation, accessibility to sources, consumer preference, environmental impact, consumer preference and several other economic and non-economic influences. Given that each of the influences has a trajectory of its own, we may not longer expect to see energy transitions as they have occurred in the West. This finding may be the consequence of a change from long waves of development or specific to energy transitions. In either case, the findings question whether long-waves of development and historical environmental transitions still exist.

Notwithstanding all these differences, it is exciting to note the lower levels of energy use, intensity and subsequent carbon emissions per capita from the developing world. The reason why this is occurring, however, is not entirely clear. It could be that these economies are simply more efficient and are developing under new technologies and social systems that facilitate greater growth are lower energy costs. On the other hand, it could be, as explained early, due to infrastructure bottlenecks, which once resolved will lead to massive increases in consumption. At the very least, it suggests a reconceptualization of the relationships between energy, urbanization and increasing wealth. A fuller understanding will demand focused comparative studies.

There are policy implications for future planning strategies in these findings. For developing countries, a diverse portfolio of energy sources is not only a better strategy then concentrating on one source, it seems the logically outcome of current conditions. In doing so, economies lower the risks related to price hikes in one area (such as those experienced during the "oil shocks" of the 1970s) and create more resilient energy systems.

At the same time, as planning an energy system includes strategic decisions, it requires addressing a number of trade-offs associated with choosing dominance in one path over others. In some cases, that the rapid developing world is facing are new choices. For example, when choosing a mix of energy carriers for an economy's growth, relying extensively on liquid fossil fuel sources, because they are currently economical, can "lock-in" that economy more quickly than in the past. Civil uses of nuclear technologies for electricity generation are both expensive and complicated and also "lock-in" an economy to a long term commitment to this source. In order to balance future requirements to flexible solutions, integrated environmental-energy policies are even more necessary in the developing context than in the developed world.

Policies often develop based upon future predictions of trends. The idea underlying some energy future predictions is that the previously experienced transitions are stable and long term trends. For example, the post-war natural gas trends were predicted to rise and over take those of petroleum, nuclear power is predicted to rise thereafter and this would be followed by fusion, which is predicted to emerge as an important force at the end of the Twenty-first Century (Marchetti 1988). If developing countries are not using fuels as predicted by the substitution model, these patterns would be less useful in prediction. The study also suggests that time- and space-effects are important drivers of these emissions. Understanding the development of these drivers and how they change greenhouse gas emissions is crucial for scenario development. Therefore in answer to the call from the Intergovernmental Panel on Climate Change, these effects should be subject to further study (Nakicenovic & Swart 2000).

Finally, this study implicates the changing susceptibility of energy transitions to policies in general. As mentioned, in the past energy transitions were stable. This may partly be because of the lack of competition between sources. Before 1820 the major fuel source was biomass and up to the 1880s, it was between coal and wood. Now, there are a number of different sources available making the market more complex and the use of fuels more relative price dependent. As oil prices reach US$80 a barrel, or as more roads are built in countries developing their private transportation sector, the use of liquid fossil fuels will be impacted. On the one hand, with increasing prices in one fuel, there are a number of other sources from which to choose from (including making liquid fuels from biomass), hence energy use and or carbon emissions will change. On the other, building more roads helps to lock-in carbon intensive practices at lower levels of national income. From this analysis energy policies are more important today and energy use and consumption may show greater response than in the past when traditional structural shift in technologies were more important. Using policy to create sustainable energy transitions portends a potential trajectory to the post fossil fuel urban era (Droege 2004).

7. Qualifications

There are several qualifications and caveats to this study. First, generalizing these patterns beg the question of how 'development' can be measured and meaningfully compared across space and time. Is it fair to compare turn of the Twentieth Century USA with 1980s Thailand, just because they may have similar GDP levels per capita (PPP)? Using purchasing power parity (PPP) per capita indicators refines international comparisons by allowing income standardization across price differences in goods and services between countries. That is, a PPP value for income in one country will match the ability of citizens to purchase the same amount of an exact set of goods and services in another country as well as their own. While using PPP per capita values is more appropriate than simply comparing GDP or GDP per capita figures, using this as a single axis for defining development leaves much out of the picture.

The level of GDP per capita or economic growth does not speak to changes in social or political structures, for example. Those attempting to address these problems often supplement economic data with social indicators including material possession acquisition such as telephones, televisions, radios and the use of banks, schools, cinemas and provision of housing, medical or educational services (see for example, any *Human Development Report* of the United Nations Development Programme). To further refine studies of development, others focus on the reduction or elimination of poverty, inequality and unemployment in the context of economic growth. Development, in this view concerns equity and distributive justice at all scales. Recently, economists have turned toward definitions that include improving the quality of life for citizens, broadly defined and especially the poor (World Bank 1991). These various definitions suggest that "[d]evelopment must therefore be conceived a multidimensional process involving major changes in social structure, popular attitudes and national institutions, as well as the acceleration of economic growth, the reduction of inequality and the eradication of poverty" (Todaro 1997, p. 16).

The notion of *time-space telescoping* fundamentally questions the underlying understanding of development portrayed only by simply economic growth. We have been careful in separating the economic growth from development and do not intend to conflate them. Rather our point is to demonstrate that various differences in development experiences (in this case energy development) exist at similar levels of economic income and during similar economic growth periods. These differences suggest that using economic income is not sufficient to understand how nations are developing.

Using urbanization level as another variable helps to demonstrate the complexity of development. In some cases economic growth outstripped that of urbanization and in some of our case economies the reverse was true. Including more variables, such as the price of fuel, will tell us more as to why some economies experienced their carriers and consumption patterns.

Second, there are data quality concerns. At the general level the data used are not comprehensive and leave out many details. Some examples have already been noted and include the use of animate power for energy and the carbon dioxide emissions related to land cover change. One important point is that many economies in the developing world are built upon large informal markets, meaning that the values of goods and services bought and sold does not appear in national accounts. This lack of information deflects the level of GDP per capita in these countries downward. Hence, the GDP per capita estimates provided are conservative. Differences between levels in the USA and developing economies may not be as great as mentioned. Moreover the data quality in the IEA category for some categories is questionable including for example, the category "Combustible, renewables and waste" (biomass).[15] For this category, we choose nations where the data quality for was evaluated as "High to Medium" (Non-OECD Europe), "High" (Latin America) or "High to Low" (Asia) (International Energy Agency (IEA) 2002a). This may not have been as effective as we had wished. Moreover, aggregating data threatens to produce the ecological fallacy. Trends identified at the national level cannot be assumed to occur at other scales. In this case, our finding that industrial intensity within the secondary economic sector is more efficient in developing countries than in the USA, for example, needs further exploration. One exciting opportunity is to compare the historical trends within a set of industries to further identify exactly which industries are more efficient than others (for a single year detailed comparisons see for example the work of Ernst Worrell).[16]

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[15] This category also includes industrial and municipal waste which is defined as that waste produced by industry, commercial, residential and public services collected by local authorities for disposal in a central location for the production of heat and/or power.

[16] See for example, http://ies.lbl.gov/, http://ies.lbl.gov/staff/worrellieua.html.

Third, our tests could not in and off themselves, provide evidence to reject the null hypothesis in each case. Rather they provide an indicative comparative synthesis at the broadest level. Certainly, this study is not the final word on this subject, but rather the opening proposal.

Finally, using only the USA as a comparative example of the experience of the developed world is unfortunate. The USA's history has proven to be extreme in terms of materials consumption (Wernick 1996) and energy use (Ayres *et al.* 2003; Cleveland *et al.* 1984). Further comparisons are necessary including those with Western European countries, Australia and New Zealand. At the same time, anecdotal information suggests that the USA's more unique trends, even among developed countries, lessens between 1820 and 1913. For example, Madisson (2003; 2005) points out that a comparison of primary energy consumption between the US and the UK converged during this period. That is, in 1820 the differences were significant. The US was consuming 2.45 tons of oil equivalent energy (toe) per capita while the UK was only consuming 0.61 toe per capita. In 1870 the differences were significantly reduced with the US still at 2.45 toe per capita, but the UK energy use expanded to 2.21 toe per capita. In 1913, the differences were 4.47 for the USA and 3.24 for the UK. By 1950, the differences grew again. The US consumed 5.68 toe per capita while the UK only consumed 3.14 toe per capita. Thereafter this difference grew. This convergence is important and suggests that the transitions within the USA during this period were not that different from what was happening in other developed countries (i.e., the UK). This was also within the period which many of the comparisons with developing economies in the article are made. Nevertheless, leaving out other developed countries limits our ability to make final conclusions concerning the comparative experiences between the generalized categories of developed and developing countries.

8. Conclusions

We conclude with some general policy recommendations for the Asia Pacific and for the developed world. We suggest that economies in the region will be well served by long term energy policies. Given the lack of clear transition trends and the rapid increases in supply and consumption, nations may want to consider ways in which (including the diversity of energy sources) rapid urbanization and economic growth can be most efficiently achieved. That is, despite the higher efficiency achieved by all these economies compared to the USA, the scale of energy needs for urbanization and the large populations within the region threatens the local, regional and global climate. Furthermore, the reliance of many economies on liquid fossil fuels in a post-peak era is not sustainable. Given the study's results, particularly attention might be paid to the transport and industrial sectors. It is these sectors were consumption is increasing most rapidly.

Urban centers typically do not have energy policies, but given the size of the agglomerations in the region, there may be a call to rationalize energy use. Energy policies for urban centers in developing countries, however, should be considered carefully. Compact city policy, for example, may not be appropriate for many locations, as the cities are already compact and further compaction in combination with current urban industrial economic structures may exacerbate exposure to air pollutants. Rather, ways to expand energy supply, through renewable sources, promote the use of efficient fuels and technologies and control motor vehicle use may be more appropriate. Certainly national and urban energy policies should be more "home grown" than taken off the shelf from the developed world.

Finally, it is from the Asia Pacific that some of the most exciting advances in energy efficiency are already being applied. These include, Singapore's electric area pricing scheme and the bus rapid transits systems that are promoted throughout the region. Indeed, there is much for the developed world to learn from the Asia Pacific experience, not only in terms of the energy histories, but also in terms of current policies.

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Table 1

Comparative descriptive statistics: GDP per capita, urbanization, TPES per capita and TFC per capita

	Period of study	Range of GDP per capita (G-K$)	Range in urbanization level (percent)	Range of TPES (toe/capita)	Range of TFC (toe/capita)
South Korea	1971-2000	2,522-12,343	40.7-81.8	0.52-4.04	0.41-2.67
Singapore	1971-2000	4,904-22,207	100-100	1.40-7.36	0.60-2.48
China	1971-2000	799-3,425	17.4-32.1	0.47-0.92	0.22-0.68
Thailand	1971-2000	1,725-6,877	13.3-21.6	0.37-1.18	0.26-0.85
Malaysia	1971-2000	2,180-7,872	33.5-57.3	0.52-2.27	0.39-1.41
Hong Kong	1971-2000	5,968-21,503	87.7-100	0.86-2.53	0.62-1.68
Indonesia	1971-2000	1,235-3,655	17.1-40.9	0.31-0.69	0.29-0.54
Vietnam	1971-2000	710-1,790	18.3-19.7	0.35-0.47	0.05-0.43
Philippines	1971-2000	1,808-2,425	33.0-58.6	0.36-0.54	0.27-0.34
Japan	1960-2000	3,986-21,069	62.5-78.7	0.86-4.12	0.60-2.81
USA (TPES)	1850-2001	1,806-28,129	15.4-77.2	1.97-8.45	
USA (TFC)	1900-2001	4,091-28,129	39.6-77.2		2.54-6.24

Table 2a

Date and GDP per capita ranges for supply and consumption comparisons over time

	TPES Period of comparison	USA Period of comparison	GDP/capita range (G-K$)	TFC Period of comparison	USA Period of comparison	GDP/capita range (G-K$)
South Korea	1971-2000	1872-1967	2,522-14,343	1979-2000	1900-1967	4,091-14,343
Singapore	1971-2000	1906-1987	4,904-22,207	1971-2000	1906-1987	4,904-22,207
China	1988-2000	1850-1891	1,806-3,425	-	-	-
Thailand	1973-2000	1850-1938	1,806-6,877	1989-2000	1900-1938	4,091-6,877
Malaysia	1971-2000	1861-1940	2,180-7,872	1983-2000	1900-1940	4,091-7,872
Hong Kong	1971-2000	1923-1986	5,968-21,503	1971-2000	1923-1986	5,968-21,503
Indonesia	1980-2000	1850-1892	1,806-3,655	-	-	-
Philippines	1971-2000	1850-1867	1,806-2,358	-	-	-
Japan	1960-2000	1898-1985	3,986-21,069	1961-2000	1900-1985	4,091-21,069

Table 2b

Date and urbanization level ranges for supply and consumption comparisons over urbanization ranges

	TPES Period of comparison	USA Period of comparison	Urbanization range (percent)	TFC Period of comparison	USA Period of comparison	Urbanization range (percent)
South Korea	1971-1994	1902-2000	40.7-77.2	1971-1994	1902-2000	40.7-77.2
China	1971-2000	1855-1886	17.4-32.1	-	-	-
Thailand	1976-2000	1850-1864	15.4-21.6	-	-	-
Malaysia	1971-2000	1888-1942	33.5-57.3	1978-2000	1900-1942	39.6-57.3
Indonesia	1971-2000	1855-1903	17.1-40.9	-	-	-
Vietnam	1971-2000	1857-1860	18.3-19.7	-	-	-
Philippines	1971-2000	1888-1943	33.0-58.6	1982-2000	1900-1943	39.6-58.6
Japan	1960-1989	1949-2000	62.5-77.2	1960-1989	1949-2000	62.5-77.2

Table 3

Comparative change in urbanization level at similar income ranges
(percent/year)

		USA
South Korea	1.46	0.49
China	0.51	0.47
Thailand	0.24	0.51
Malaysia	0.79	0.50
Indonesia	0.94	0.47
Philippines	0.92	0.49
Japan*	0.87	0.47

*For this analysis, Japanese data includes the range 1920-2000
In 1960, the year that the energy data begin, Japan was
approximately 63 percent urbanized.

Table 4

Comparision of emergence of various energy carriers, dates, GDP per capita and urbanization levels

	Emergence of crude oil and petrol as primary energy carriers			Emergence of natural gas as primary energy carrier			Emergence of hydro as primary energy carrier			Emergence of nuclear as primary energy carrier			Emergence other renewa as primary er carrier	
	Year	GDP per capita	Urbanization level	Year	GDP per capita	Urbanization level	Year	GDP per capita	Urbanization level	Year	GDP per capita	Urbanization level	Year	GDP per capita
South Korea	na	before 2,522	before 40.7	1987	8,704	68.3	1990	8,704	73.8	1978	4,064	53.0	-	
Singapore	na	before 4,904	before 100.0	1992	15,537	100.0	-			-			1996	19,963
China	na	before 799	before 17.4	1977	895	18.3	1993	2,277	28.7	-			-	
Thailand	na	before 1,725	before 13.3	1982	2,744	17.3	1995	6,573	19.9	-			-	
Malaysia	na	before 2,180	before 33.5	1974	2,688	36.8	1983	4,096	44.2	-			-	
Hong Kong	na	before 5,968	before 88.1	1996	21,075	100.0	-			-			-	
Indonesia	na	before 1,235	before 17.1	1994	3,146	34.5	-			-			1995	3,348
Vietnam	na	before 754	before 18.3	1998	1,672	19.6	1993	1,214	19.6	-			-	
Philippines	na	before 1,808	before 33.0	-			-			-			1979	2,323
Japan	na	before 3,986	before 62.5	na	before 3,986	before 62.5	na	before 3,986	before 62.5	1970	9,714	71.2	1983	14,307
USA	1876	2,570	27.2	1885	3,270	31.5	1885	3,270	31.5	1967	14,330	72.5	1980	18,577

Notes:

Emergence occurs when value>0.01 toe/capita

na=data not available, emergence occurred prior to dates in database

"-" not yet emerged

Table 5

Comparison of emergence of electricity, dates, GDP per capita and urbanization levels

	Emergence of electricity			
	Year	level (toe/capita)	GDP per capita	Urbanization level
South Korea	Before 1971	0.024	Before 2,522	Before 42.0
Singapore	Before 1971	0.085	Before 4,904	Before 100.0
China	Before 1971	0.012	Before 799	17.4
Thailand	1972	0.011	1,748	14.0
Malaysia	Before 1971	0.025	Before 2,180	Before 34.3
Hong Kong	Before 1971	0.112	Before 5,968	Before 88.1
Indonesia	1989	0.011	2,352	29.5
Vietnam	1984	0.010	895	19.5
Philippines	Before 1971	0.018	Before 1,807	Before 33.5
Japan	Before 1960	0.087	Before 3,986	Before 62.5
USA	**1905**	**0.011**	**4,642**	**42.5**

Notes:

Emergence occurs when value>0.01toe/capita

Table 6: Comparative change in total primary energy supply (TPES) under similar GDP per capita income and urbanization ranges

6a

Changes in supply over similar income ranges (koe/capita/year)

	Change in TPES	USA Change in TPES
South Korea	124.27	43.59
Singapore	187.21	58.55
China	17.12	11.08
Thailand	32.07	33.18
Malaysia	61.24	36.90
Hong Kong	59.45	75.94
Indonesia	15.53	11.28
Philippines	5.10	-5.49
Japan	76.29	57.67

6b

Changes in supply over similar urbanization levels (koe/capita/percent urban)

	Change in TPES	USA Change in TPES
South Korea	60.04	142.13
China	27.27	25.59
Thailand	116.99	-10.36
Malaysia	76.77	83.22
Indonesia	16.32	38.56
Vietnam	-16.08	-14.47
Philippines	5.53	83.99
Japan	161.99	286.82

Table7: Comparative change in total final consumption (TFC) under similar GDP per capita income and urbanization ranges

7a

Changes in consumption over similar income ranges (koe/capita/year)

	Change in total final consumption	USA Change in total final consumption
South Korea	105.29	29.38
Singapore	74.79	34.77
Thailand	31.69	13.64
Malaysia	53.09	13.82
Hong Kong	43.26	42.78
Japan	45.4	36.0

7b

Changes in consumption over urbanization levels (koe/capita/percent urban)

	Change in total final consumption	USA Change in total final consumption
South Korea	40.70	76.88
Malaysia	57.47	40.16
Philippines	2.44	44.64
Japan	107.14	105.34

Table 8a

Comparative change in primary energy supply over similar GDP ranges, by carrier
(koe/capita/year)

	Coal	Biomass	Petrol, oil and NG	Hydro	Nuclear	Modern Renewables	Total primary energy supply	USA Coal	USA Biomass	USA Petrol, oil and NG	USA Hydro	USA Nuclear	USA Modern Renewables	USA Total primary energy supply
South Korea	19.71	1.20	81.85	0.14	21.36	0.03	124.27	5.68	-12.15	32.39	16.73	0.03	0.00	43.59
Singapore	0.04	-0.14	186.85	0.00	0.00	0.44	187.21	-27.15	-2.47	52.07	31.14	3.73	0.15	58.55
China	9.92	-0.78	7.10	0.58	0.36	0.00	17.12	31.11	-24.40	3.00	1.35	0.00	-	11.08
Thailand	5.63	0.84	25.43	0.12	0.00	0.00	32.07	37.40	-21.19	12.02	4.17	0.00	0.00	33.18
Malaysia	2.57	0.08	57.79	0.81	0.00	0.00	61.24	35.73	-20.00	15.12	5.17	0.00	0.00	36.90
Hong Kong	36.98	-0.10	19.65	0.00	0.00	0.00	59.45	-23.98	-1.11	56.49	37.63	5.27	0.21	75.94
Indonesia	2.96	-0.19	11.97	0.16	0.00	0.63	15.53	31.77	-24.81	2.83	1.46	0.00	0.00	11.28
Philippines	1.57	-1.05	0.39	0.13	0.00	4.05	5.10	12.34	-18.29	0.45	0.00	0.00	0.00	-5.49
Japan	4.55	1.78	49.74	-0.07	19.39	0.90	76.29	-22.24	-3.61	50.29	29.37	2.70	0.10	57.67

Table 8b

Comparative change in primary energy supply over similar GDP ranges, by carrier
(koe/capita/percent urban)

	Coal	Biomass	Petrol, oil and NG	Hydro	Nuclear	Modern Renewables	Total primary energy supply	USA Coal	USA Biomass	USA Petrol, oil and NG	USA Hydro	USA Nuclear	USA Modern Renewables	USA Total primary energy supply
South Korea	12.51	0.25	35.80	0.15	11.33	0.01	60.04	-52.06	-5.89	183.60	2.11	13.43	0.64	142.13
China	21.12	-1.02	6.27	0.72	0.19	0.00	27.27	64.90	-50.30	10.98	0.00	0.00	0.00	25.59
Thailand	20.05	4.25	91.92	0.51	0.00	0.00	116.99	25.40	-36.59	0.83	0.00	0.00	0.00	-10.36
Malaysia	3.23	0.11	72.43	1.02	0.00	0.00	76.77	34.68	-23.44	70.00	1.93	0.00	0.00	83.22
Indonesia	2.45	-0.31	13.47	0.16	0.00	0.55	16.32	87.90	-58.08	7.82	0.93	0.00	0.00	38.56
Vietnam	3.37	0.89	-27.94	7.61	0.00	0.00	-16.08	10.13	-25.95	1.35	0.00	0.00	0.00	-14.47
Philippines	1.70	-1.20	0.68	0.13	0.00	4.22	5.53	33.37	-23.26	71.87	1.95	0.00	0.00	83.99
Japan	1.01	1.96	136.59	-0.07	21.82	0.67	161.99	10.46	3.74	208.07	84.55	56.36	2.77	286.82

Table 9a

Comparative change in energy consumption, by product, over similar GDP ranges (koe/capita/year)

	Electricity	Total final consumption	Electricity	Total final consumption
South Korea	17.69	105.29	5.84	29.38
Singapore	17.63	74.79	10.61	34.77
Thailand	6.59	31.69	2.49	13.64
Malaysia	11.56	53.09	2.59	13.82
Hong Kong	13.45	43.26	13.47	42.78
Japan	14.19	45.44	9.54	36.01

Table 9b

Comparative change in energy consumption, by product, over similar urbanization ranges (koe/capita/percent urban)

	Electricity	Total final consumption	Electricity	Total final consumption
South Korea	6.13	40.70	27.45	76.88
Malaysia	11.75	57.47	5.88	40.16
Philippines	0.71	2.44	6.26	44.64
Japan	86.32	107.14	72.49	105.34

Table 10a

Comparative change in energy consumption over similar GDP ranges, by sector (koe/capita/year)

	Industrial	Commercial	Residential	Transport	Total consumption	USA Industrial	USA Commercial	USA Residential	USA Transport	USA Total consumption
South Korea	47.63	21.25	-1.19	29.31	105.29	7.77	7.90	16.61	9.82	29.06
Singapore	36.91	5.62	1.95	29.84	74.79	6.85	10.78	17.15	13.60	34.71
Thailand	16.17	2.25	-0.99	13.15	31.69	-0.66	0.26	2.99	5.13	13.69
Malaysia	23.65	4.03	2.97	20.44	53.09	-1.81	0.28	4.13	5.78	13.86
Hong Kong	-0.55	10.52	3.47	29.56	43.26	13.63	13.87	20.18	15.98	42.81
Japan	8.13	11.35	8.40	15.84	45.44	8.83	9.95	16.45	13.31	35.93

Table 10b

Comparative change in energy consumption over similar urbanization levels, by sector (koe/capita/percent urban)

	Industrial	Commercial	Residential	Transport	Total consumption	USA Industrial	USA Commercial	USA Residential	USA Transport	USA Total consumption
South Korea	16.02	7.70	2.73	11.06	40.70	11.71	25.65	38.51	34.10	76.90
Malaysia	25.02	4.60	2.86	22.75	57.47	-24.16	0.73	11.34	10.34	17.19
Philippines	1.89	1.44	-4.04	4.67	2.44	2.26	0.68	9.66	17.14	44.74
Japan	37.38	19.17	16.09	28.00	107.14	-0.77	32.83	28.06	54.18	105.34

Table 11

Comparison of timing of transitions and level of economic development

	Biomass to coal	Biomass to liquid and gas fossil fuels	Biomass to hydro	Coal to liquid and gas fossil fuels	Coal to hydro	Biomass to advanced technologies	Coal to advanced technologies
South Korea	na	na	na	na	-	na	-
Singapore	na	na	na	na	-	-	-
China	na	1997	-	-	-	-	-
Thailand	na	1980	-	na	-	-	-
Malaysia	-	na	-	na	-	-	-
Hong Kong	na	na	-	na	-	-	-
Indonesia	-	1989	-	na	-	-	-
Vietnam	-	-	-	na	-	-	-
Philippines	na	na	-	na	-	1983	2000
Japan	na	na	na	1963	-	na	-
	1st set of transitions			2nd set of transitions		3rd set of transitions	
USA	1883	1916	1926	1950	1958	1974	-

Transitions occur when the share of one carrier passes that of the other

na: data not available, occurrence prior to record

"-": transition has yet to occur

Table 12a

Comparative energy consumption during similar GDP ranges, by major product (toe/capita)

						USA				
	Coal	Biomass	Petrol, oil and NG	Electricity	TFC	Coal	Biomass	Petrol, oil and NG	Electricity	TFC
South Korea	4.92	0.02	25.10	4.53	34.81	121.83	21.97	114.04	9.00	266.84
Singapore	0.00	0.04	41.81	8.91	50.76	115.65	22.68	203.76	23.13	365.26
Thailand	0.57	1.83	4.98	1.11	8.49	89.77	15.82	26.83	1.74	134.16
Malaysia	0.53	1.29	13.02	2.41	17.25	93.07	16.34	30.27	1.97	141.64
Hong Kong	0.03	0.29	24.55	8.32	33.19	69.87	14.96	192.77	21.80	299.43
Japan	7.44	0.38	55.71	15.40	79.07	127.56	25.73	196.59	21.53	371.43

Table 12b

Comparative energy consumption during similar urbanization ranges, by major product (toe/capita)

						USA				
	Coal	Biomass	Petrol, oil and NG	Electricity	TFC	Coal	Biomass	Petrol, oil and NG	Electricity	TFC
South Korea	5.67	0.00	15.76	2.65	24.12	126.21	26.72	257.06	35.73	446.07
Malaysia	0.55	1.64	15.03	2.68	19.91	97.06	16.83	34.04	2.25	150.18
Phillippines	0.19	2.79	2.55	0.59	6.11	99.32	17.07	36.00	2.42	154.80
Japan	6.13	0.18	37.67	9.44	53.46	21.02	9.86	209.61	32.44	273.28

Figure 1: USA Energy Transitions

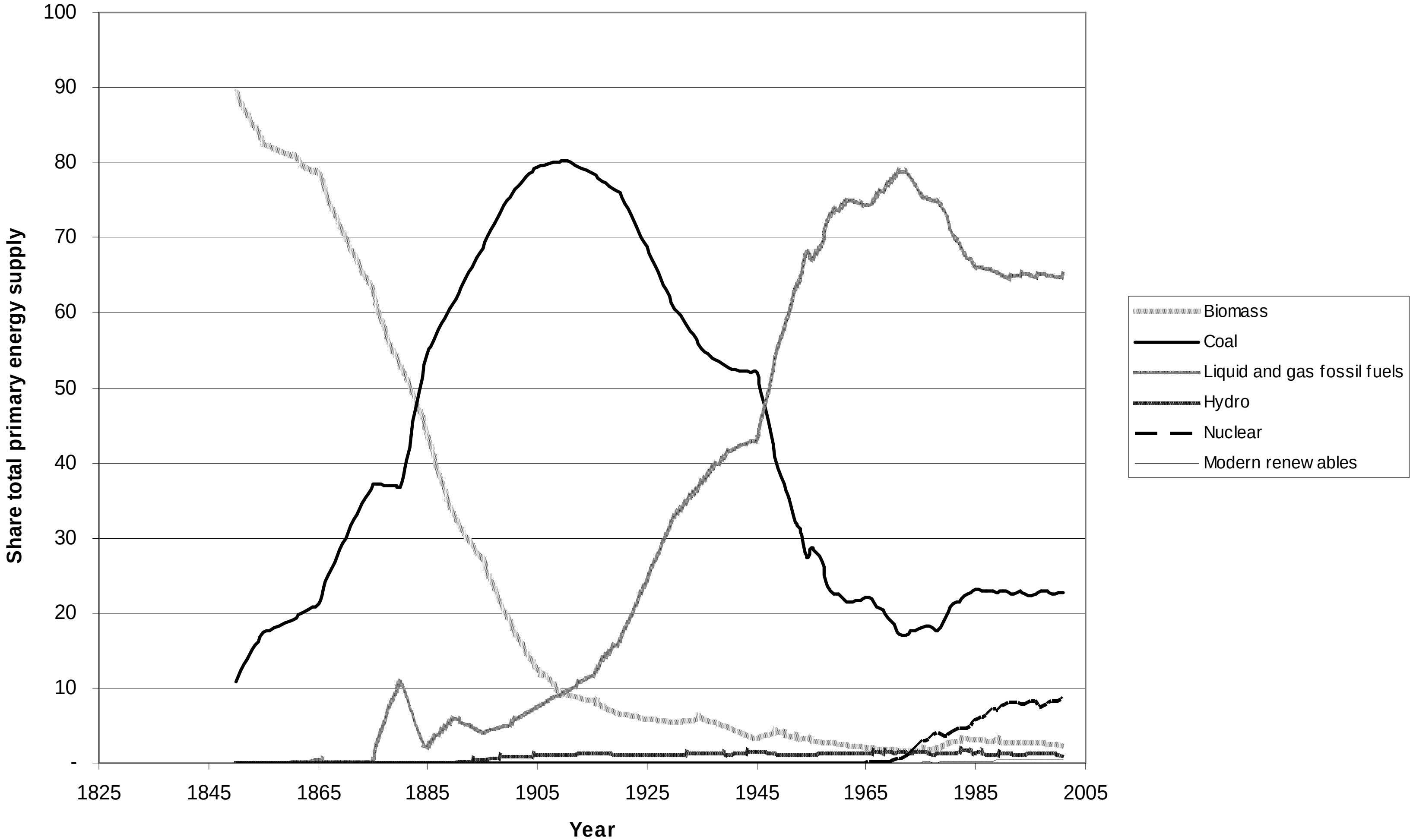

Figure 2: Comparative urbanization levels by GDP per capita, USA and selected Asia-Pacific economies

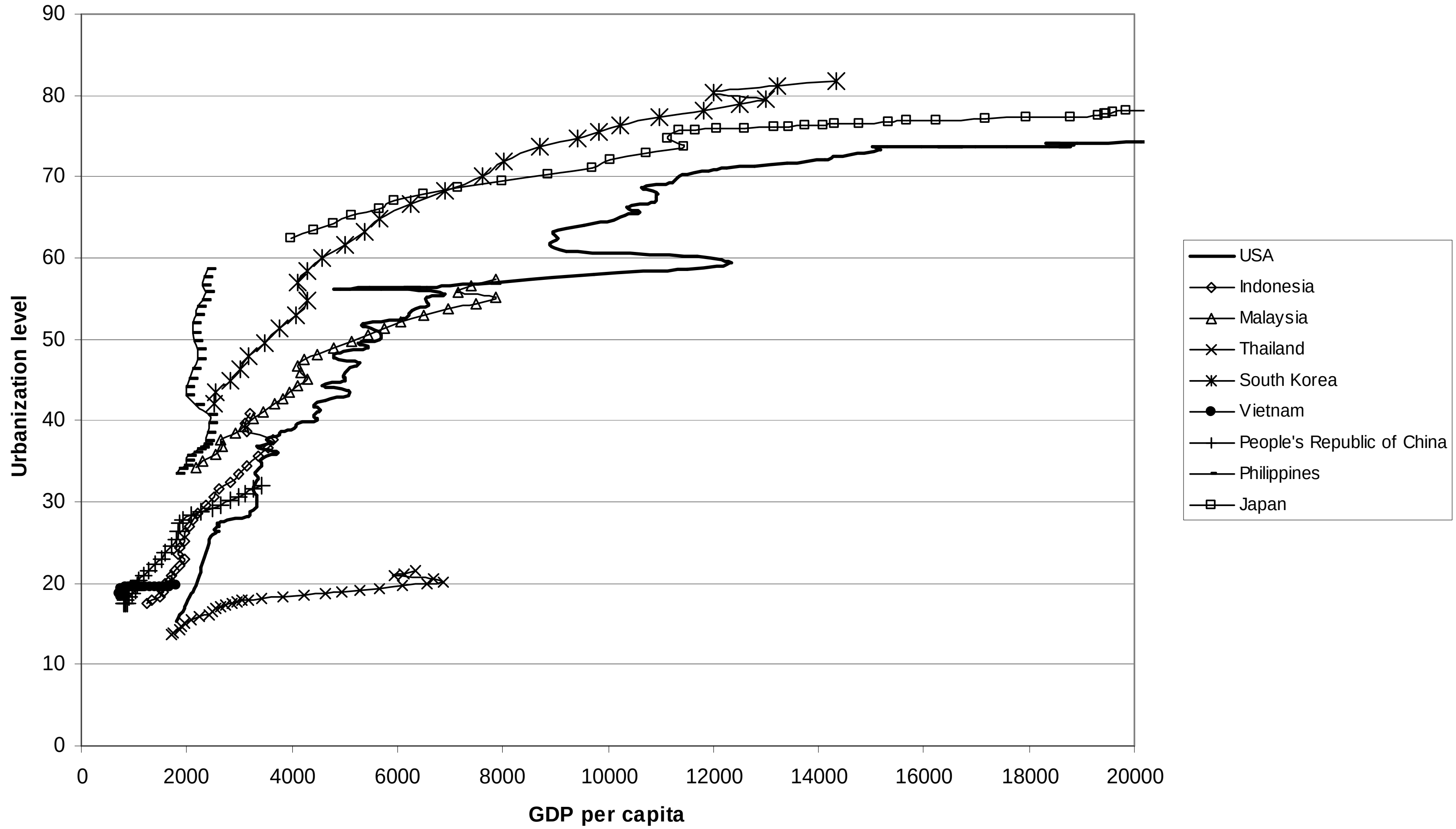

Figure 3: Comparative change in industrial efficiency over GDP per capita, USA and selected Asia-Pacific economies

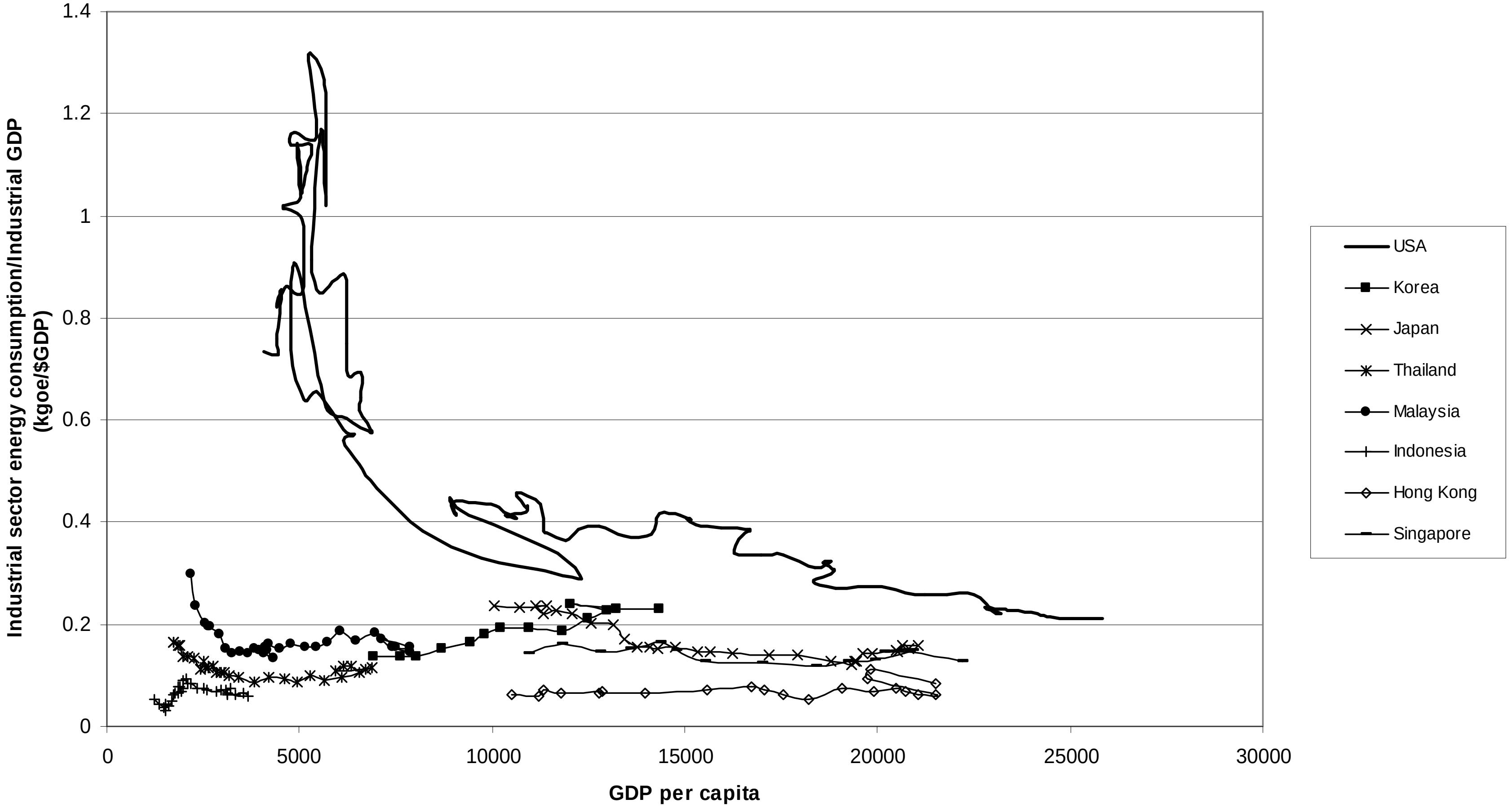

Figure 4: Comparative changes in carbon emissions by GDP per capita, USA and selected Asia-Pacific economies

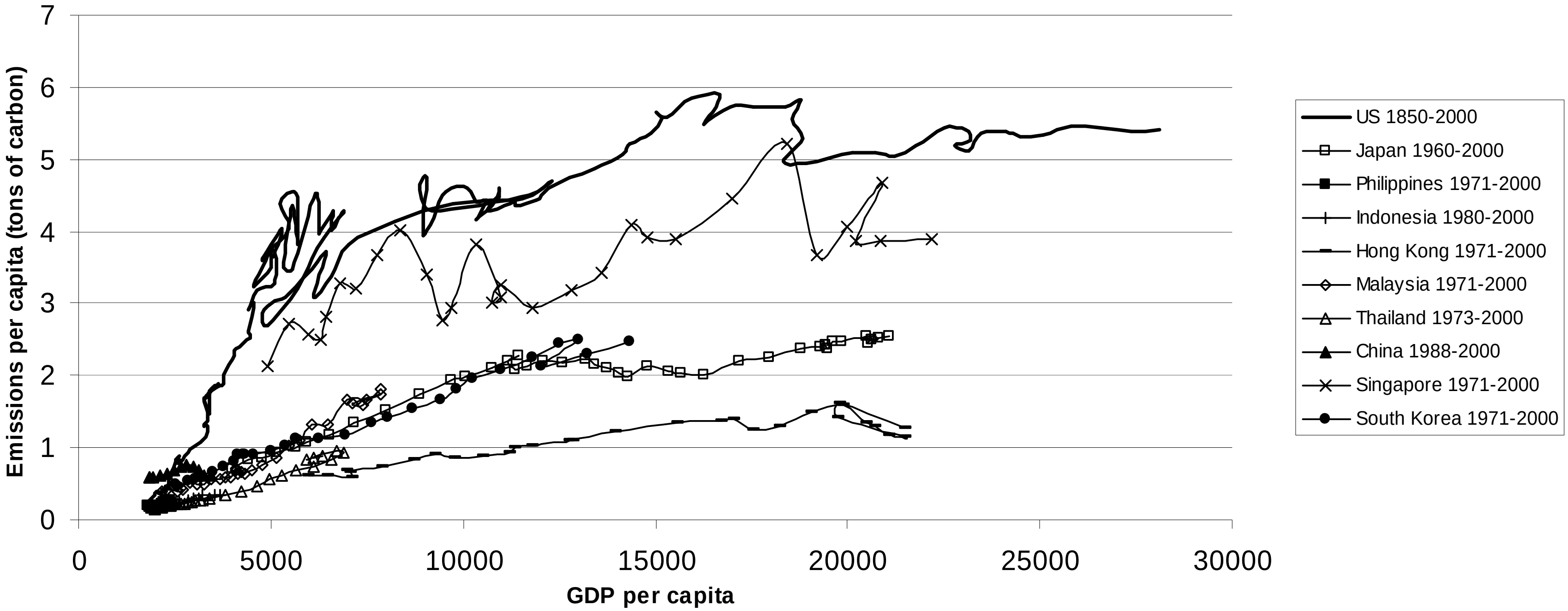

Figure 5: Comparative carbon emissions per level of urbanization, USA and selected Asia-Pacific economies