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Looking for a New Order in Urban Energy Efficient Strategies in Urban Studies

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ABSTRACT: More than 50% of the global population already lives in urban settlements which are projected to absorb almost all the global population growth to 2050, amounting to some additional three billion people. Over the next decades the increase in rural population in many developing countries will be overshadowed by population flows to cities. Rural populations globally are expected to peak at a level of 3.5 billion people by around 2020 and decline thereafter. Given the robust trends toward a convergence of much of the developing world to levels of urbanization already found in the developed world, the energy and sustainability challenges of equitable access to clean-energy services, of energy security, and of environmental compatibility at local through global scales cannot be addressed without explicit consideration of urban energy systems and their specific sustainability challenges and opportunities. Energy-wise, the world is already predominantly urban. It is estimated that between 60–80% of final energy use globally is urban. Hereby various urban elements play significant role in urban energy consumption rate. Knowing these key drivers and providing appropriate strategies may be an important action toward a more efficient urban future. Considering the aforementioned challenges, acquiring a comprehensive view on key drivers and therefore comprehensive urban energy efficiency strategies is the fundamental aim of the present research. Based on this aim, a wide literature review on global urban energy issues is done to provide comprehensive knowledge of the most important urban energy key drivers. In the next step, a comprehensive urban energy efficiency strategies is delivered in different urban dimensions.

Keywords: Urban Energy Efficiency, Urban Energy Drivers, Urban Planning, Planning Strategies and Measures.

INTRODUCTION

With cities accounting for half the world's population today, and two-thirds of global energy demand, urbanization is exacting a serious toll on the environment. As rapid urban growth continues, energy use in cities and associated levels of greenhouse gas (GHG) emissions are projected to continue unabated; current projections indicate that approximately 70 percent of the world's population will live in cities by 2050, producing some 80 percent of the world's GHG emissions. Unfortunately, most of this urban growth will take place in developing countries, where the vast majority of people remain underserved by basic infrastructure service and where city authorities are under-resourced to shift current trajectories. Further, the developing regions of Africa and Asia are where the most rapid urbanization is taking place, and they are least able to cope with the uncertainties and extremities of climate impacts. The development and mainstreaming of energy-efficient and low-carbon urban pathways that curtail climate impacts without hampering

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the urban development agenda thus are essential to meeting such challenges. Reducing long-term energy use through efficiency also enhances energy security by decreasing dependence on imported and fossil fuel. In addition, lower energy costs free up a city's resources to improve or expand services while providing important local co-benefits, creating new jobs, enhancing competitiveness, improving air quality and health, and providing a better quality of life (Ranjan K. Bose 2010). Within this complex system of interaction among different urban elements and sub-systems, identifying and analyzing the main important and influential energy drivers which is the main research question will take a significance role in controlling, mitigating and optimization of the energy use in urban context. Through analyzing these key-drivers, comprehensive policies, strategies and measures are definable. This is the main aim of the existing paper. Such a comprehensive overlook on urban energy efficiency is the existing gap in many conducted researches up to moment. This could enhance the understanding of the importance of urban energy debate and the way to face with in urban studies.

PROCESS OF THE RESEARCH

The first step of the research includes, a general overview on urban energy crisis, which is considered as one of the most urban challenges in global contemporary urban development path. In order to achieve a comprehensive overview on urban energy efficiency a wide analysis and identification of all influential elements and key drivers is essential. Subsequently, identifying the key drivers, and analysis of the impact and role of each drivers and element on energy usage in cities, is one of the main aims of the present research. There has been up to investigate various literature and experiences on providing frameworks for urban energy efficient development plans and strategies, but the most important characteristics of this research is provision of a comprehensive proposes and strategies which include the most important elements of urban energy efficiency. All these drivers effect the urban energy use directly and indirectly. Therefore a key solution is to control and optimize the urban energy use considering all these key drivers which is an important step in efficiency planning and studies. The schematic process of the research is provided as the following figure.

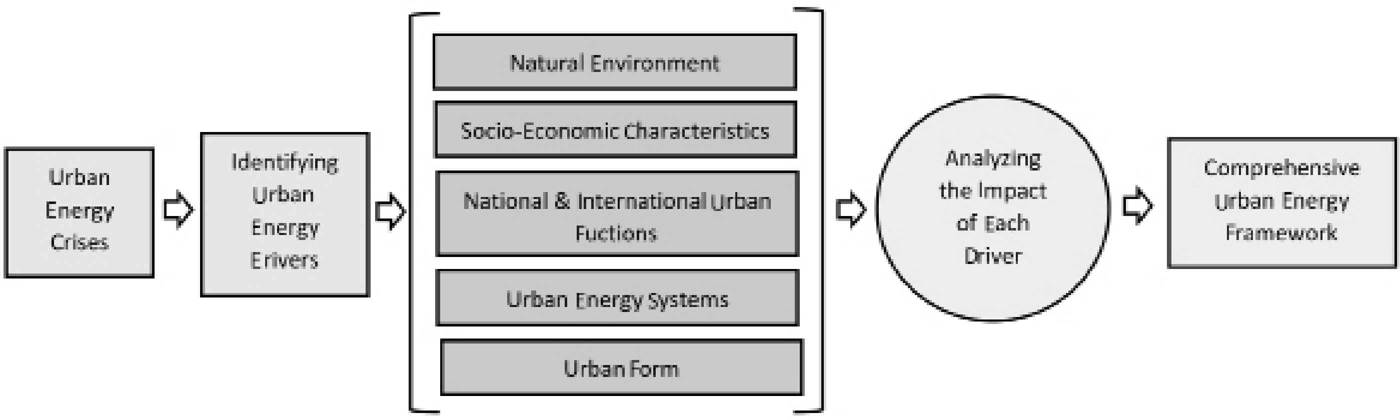

Fig. 1. Process of the Research

DRIVERS OF URBAN ENERGY USE AND MAIN POLICY LEVERAGES

This section synthesizes existing knowledge of the main drivers of urban energy use and related policy considerations. The factors that determine urban energy use can be classified into a few major groups: natural environment (geographic location, climate, and resource endowments), socioeconomic characteristics of a city (household characteristics, economic structure and dynamics, demography), national/international urban function and integration (i.e., the specific roles different cities play in the national and global division of labor, from production and a consumption perspectives), urban energy systems characteristics including governance and access (i.e., the structure and governance of the urban energy supply system and its characteristics), and last, but certainly not least, urban form (including the built urban environment, transportation infrastructure, and density and functional integration or separation of urban activities), as shown in Fig. 2.

These factors do not work in isolation, but rather are linked and exhibit feedback behavior, which prohibits simple linear relations with aggregated energy use. The interaction between the driving factors may change from city to city – moreover, many of the factors are dynamic and path dependent, i.e., are contingent on historical development. There is, however, one factor that underpins all these determinants in a complex and nondeterministic way: the history of a city. The location of a city and the initial layout of its urban form are determined historically: witness the difference between sprawling North American cities that developed in the age of the automobile and older, compact European cities that developed their cores in the Middle Ages. Likewise, the economic activities of a city often stem from historical functions, whether as a major harbor, like Cape Town and Rotterdam, an industrial center, like Beijing now and Manchester historically, or a market and exchange center, like London, New York, and Singapore. These historical legacies may have long-term implications on urban energy use. However, there are also cases in which

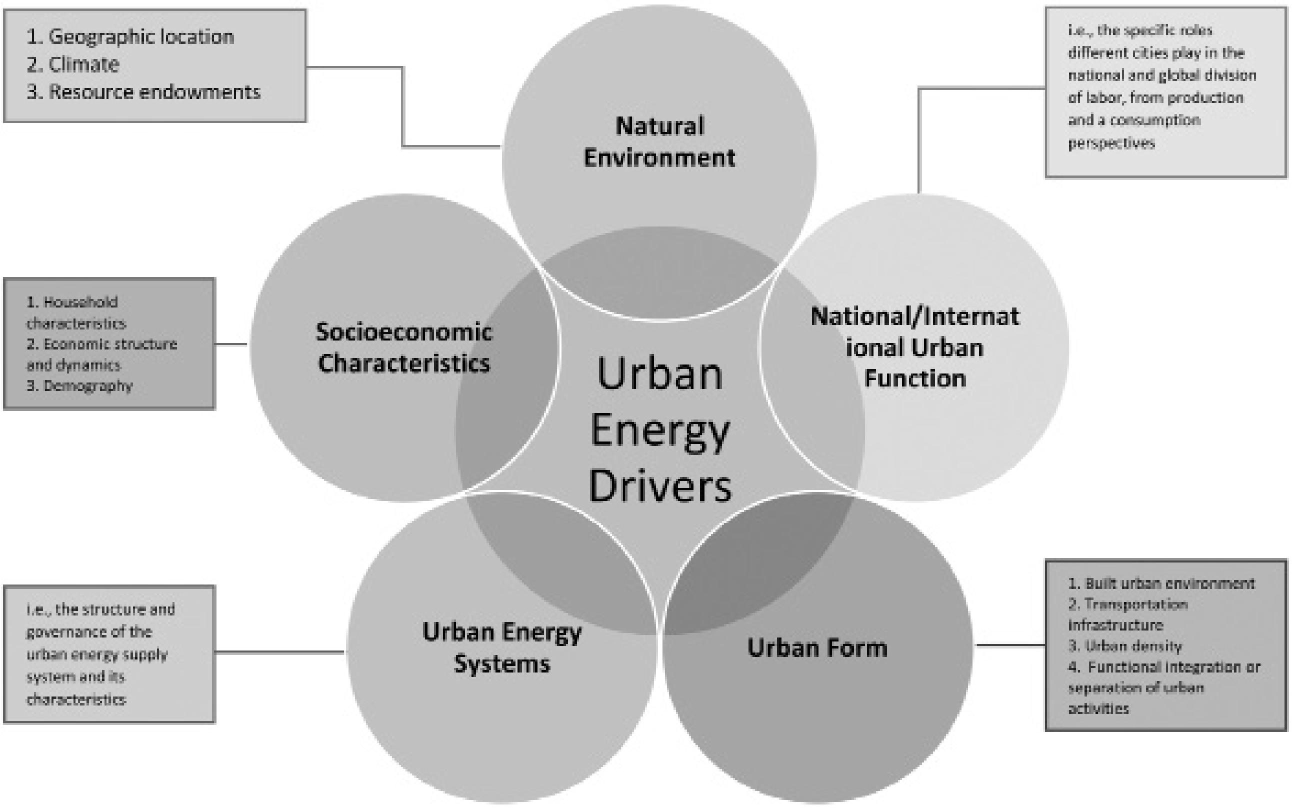

Fig. 2. Urban Energy Key Drivers (Adopted from Grubler et al., 2012)

relatively rapid changes in the historical layout and/or the economic role of a city occur. This can be the result of war, natural disasters, or rapid socioeconomic transitions, such as industrialization or deindustrialization. Examples are Tokyo after World War II, Beijing in the past decade as transformed by China's accelerated transition from an agrarian to an industrial society, or many Eastern European cities after the fall of the iron curtain in 1989 and the subsequent economic restructuring from a centrally planned toward a market economy (GEA, 2012, p. 1357).

Driver 1: Natural Environment

Climate is an important factor in determining final energy use, especially for heating and cooling demands. Its influence on energy use can be measured through the metrics of heating and cooling degree days, which, in combination with the thermal quality of buildings and settings for indoor temperature, determine energy use. Urban energy demand is, in principle, not markedly different in its climate dependence than that in nonurban settings or national averages, but it is structured by the influence of other variables, such as urban form (e.g., higher settlement densities lead to smaller per capita residential floor areas), access to specific heating fuels, or income (e.g., more affluent urban households use more air conditioning), that can amplify or dampen the effect of climate variations on urban energy demand. National studies illustrate the quantitative impact of climate variables on energy demand. For example, Schipper (2004) reports differences in space-heating energy use (measured as useful energy) normalized to heating degree days and square meters living space for seven industrial countries.

The relationship between climate and urban energy use is two-sided: climate not only influences urban energy demand, but urban areas also influence their local climate through the 'urban heat island' effect. This effect can reduce the heat demand during winter, but also enhance the need for cooling in the summer, especially in warm and humid climates. Studies show increases in the summer time cooling load in tropical and mid-latitude cities (Dhakal et al., 2003, p. 1487). To a certain extent cities inherit the resource dependencies of their respective countries, which explains, for instance, the continued use of coal in urban areas in countries endowed with large coal resources. The connection to national energy systems and their dependence on the resource base is especially pronounced for power generation, since cities often draw electricity from the national grid. In some cases, urban power plants are designed to use local resources, such as hydropower, geothermal, or wastes, but these potential resources are usually extremely limited in urban areas and provide only a small contribution to the high energy demand associated with high urban population and income densities. On the distribution and end-use side, district heating and cooling infrastructures, which allow large economies of scale, cogeneration, and energy-efficient 'cascading' schemes, are specific urban-efficiency assets, but only economically possible when the density of demand is above a threshold that warrants the investment (GEA, 2012, p. 1359).

Driver 2: Socioeconomic Characteristics

The positive correlation between income and (final) energy use is long established in the traditional energy literature, especially for analyses at the national level. For the household level, correlations between income and energy use have been shown for the Netherlands (Vringer and Blok, 1995, p. 893), India (Pachauri and Spreng, 2002, p. 511), Brazilian cities (Cohen et al., 2005, p. 555), Denmark (Wier et al., 2001, p. 259), and Japan (Lenzen et al., 2006, p. 181), with similar results for GHG emissions in Australia (Dey et al., 2007, p. 280) and CO_2 emissions in the United States (Weber & Matthews, 2008, p. 379). For Sydney, Lenzen et al. (2004) showed that urban household energy increases with household expenditure, and that most of this increase results from the energy embodied by goods and services, since direct final energy use, in contrast, increases only slowly with expenditure (albeit from high baseline levels).

Figure 3 show the urban income-energy relationship from a production perspective. It shows that income and energy increase together, albeit along distinctly different trajectories, which illustrates path dependency. Income is therefore far from the sole determinant of the level of energy use: for instance, Beijing and Shanghai have a higher average energy use than Tokyo, despite a lower per capita income. In addition to income, demographic factors play a role in determining urban energy use (Liu et al., 2003, p. 530; O'Neill et al., 2010). For instance, studies suggest that household size, that is the number of people living in one household, plays a role in energy use: above two people per household, economies of scale can reduce the energy used per capita. This phenomenon is observed in India (Pachauri, 2004, p. 1723), Sydney (Lenzen et al., 2004, p. 375), the United States (Weber and Matthews, 2008, p. 379), and Denmark and Brazil (Lenzen et al., 2006, p. 181). In Japan, in contrast, larger household sizes correlate with slightly larger energy use

(Lenzen et al., 2006, p. 181). The evidence for age is mixed. In Sydney, increasing age is correlated with higher residential but lower transportation energy use (Lenzen et al., 2004, p. 375). Larivi.e.re and Lafrance (1999) found a positive correlation between residential electricity use with age for Canadian cities.

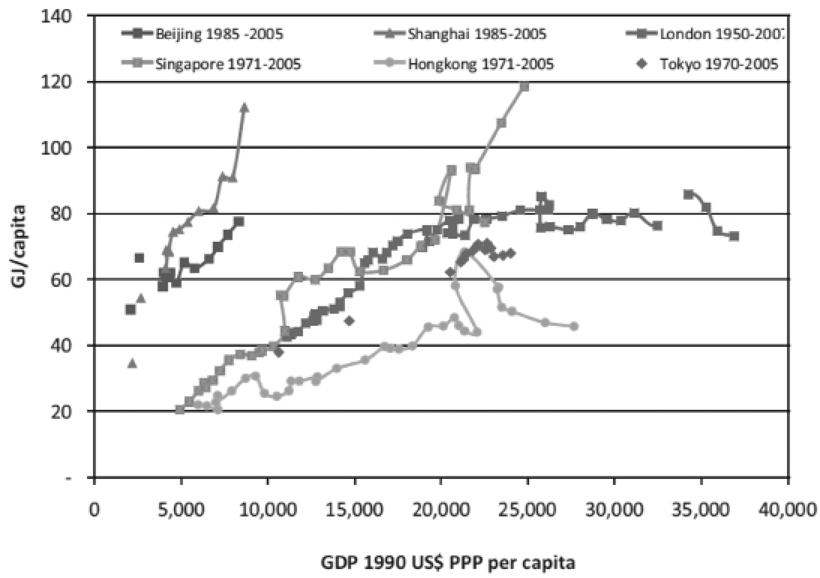

Fig. 3. Longitudinal Trends in Final Energy (GJ) Versus Income (At PPP, in Int1990$) per Capita for Six Megacities. Not the Path-Dependent Behavior (Schulz, 2010a)

Driver 3: National/International Urban Function and Integration

A city's function in regional, national, and international economies has a strong bearing on its energy signature when measured from a production perspective. In the extreme case of Singapore, a major center for oil refining and petrochemical production and a major international transport hub, the energy use associated with international trade in oil products, shipping, and air transport (usually subsumed[1] under 'apparent consumption' of the city's primary energy use) is four times larger than the direct primary energy use of Singapore and more than eight times larger than the final energy use of the city. The 35 largest cities in China (China's key industrialization and economic drivers) are responsible for 40% of the nation's GDP and contribute over proportionally to national commercial energy use (Dhakal, 2009, p. 4208). Cities often specialize in certain types of manufacturing, commercial, or administrative functions. Some urban areas are also large transport hubs, such as London for air transit, or Cape Town and Rotterdam for shipping, that adds significantly to urban energy use, and is too often omitted from urban energy and GHG accounts. For instance, London's twin functions as a major international airport hub and as a global city result in an energy use from air transport that corresponds to one-third of London's total (direct) final energy use (Mayor of London, 2004). A service-based economy can generate the same income with less energy than an economy based on the production of goods. Because of city per capita energy use in advanced, service-oriented economies is lower than national averages.

Driver 4: Energy Systems Characteristics: Governance, Access, and Cogeneration

The organization of energy markets and their controls at the urban level also influence urban energy use. Alternative organizational forms, such as state or municipal monopolies, cartels, or free-markets, impact access, affordability, and the possibility of implementing energy-saving policies. Localized energy monopolies may work closely with urban governments to further local policies, whereas free-market structures often challenge the enactment of environmental or social policies, such as renewable mandates, or the possibility of performance contracting. Many industrialized cities have put in place City Climate Actions Plans, which are expected to reduce or dampen energy use or promote shifts to renewables in the coming decades, but their success will depend on the links between city government and local energy providers (GEA, 2012).

Driver 5: The Urban Form: The Built Urban Environment and its Functions [2]

The built urban environment comprises the totality of the urban building stock: residential, commercial, administrative, and industrial buildings, their thermal quality and spatial distribution. It also includes built urban infrastructures for transport, energy, water, and sewage. This environment is one of the key components for understanding the special characteristics of urban energy use as compared to rural, economy-wide, or global patterns. The unique concentration and overall scale of the built urban environment allow both economies of scale and economies of scope to occur, and thus provide options for energy efficiency gains (GEA, 2012). The very important point is that, most of the aforementioned drivers are not directly influenced through urban planning and design procedures. Figure 5 shows the main influential areas through urban planning and design procedures.

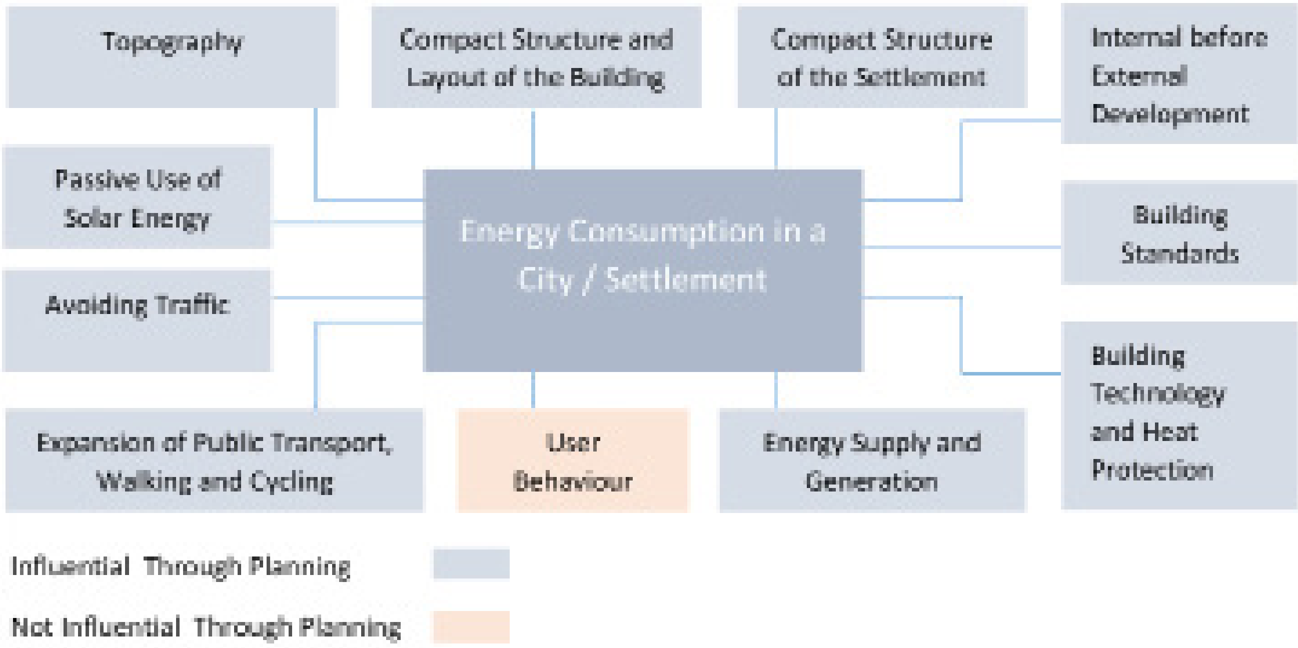

Fig. 5. Influence of Urban Planning on the Energy Consumption of a City (Peseke et al., 2010)

Approaches to energy consumption reduction can be achieved through planning principles, such as the mixture of functions, the acceptable density of the model or the "city of short distances". Furthermore, urban development should not be viewed in isolation from the traffic planning and energy supply, but rather are in exchange with these sectors. By reducing the volume of traffic and the shift to public passenger transport itself energy consumption minimization approaches arise. But also by an increased efficiency of energy supply and use of energy produced from renewable energy sources, paving the way for an energetic city planning are provided. The most important energy oriented criteria in frame of urban planning and design are presented in table 1. The main focal points are on settlement area, urban compactness, passive energy absorption, transport oriented issues, buildings and energy systems.

Table 1. Energy Efficiency Checklist for Urban Planning and Design (Peseke and Roscheck, 2010)

Field of Action	Criteria	Sub-Criteria
Settlement Area	Internal Before External Development	Inner City Densification
Settlement Area	Internal Before External Development	Use of Permitted Planning Law
Urban Planning & Design	Compact Structure and Layout of the Building	Optimization of The A(Area)/V(Volume)E Ratio
Urban Planning & Design	Compact Structure and Layout of the Building	Compressed Design / Building Typology
Urban Planning & Design	Compact Structure and Layout of the Building	Length of the Building Body
Urban Planning & Design	Compact Structure and Layout of the Building	Depth of the Building
Urban Planning & Design	Compact Structure and Layout of the Building	Number of Floors
Urban Planning & Design	Compact Structure and Layout of the Building	Roof Shape / Roof Pitch
Urban Planning & Design	Topography	Utilizing the Topographical Conditions to Minimize the Thermal Energy Consumption
Urban Planning & Design	Topography	Wind Protection
Urban Planning & Design	Passive Use of Solar Energy	Building Orientation
Urban Planning & Design	Passive Use of Solar Energy	Façade Considerations
Urban Planning & Design	Passive Use of Solar Energy	South-Facing Roof Surfaces
Urban Planning & Design	Passive Use of Solar Energy	Shading by Neighboring Buildings / Vegetation
Transport	Avoiding Traffic	Mixed Use
Transport	Avoiding Traffic	Distances to Facilities
Transport	Avoiding Traffic	Traffic Areas/Surfaces
Transport	Avoiding Traffic	Use of Existing Infrastructure
Transport	Expansion of Public Transport, Walking and Cycling	Prioritizing Public Transport in Road Space
Transport	Expansion of Public Transport, Walking and Cycling	Strengthening of Cycling and Walking
Building	Building Technology/Heat Protection	Structural Thermal Insulation in Existing Buildings
Building	Building Technology/Heat Protection	Use of Modern Heating Technology for Existing Buildings
Building	Building Technology/Heat Protection	Use of Ventilation Systems in Existing Buildings
Building	Building Standards	Construction of Energy-Efficient Houses
Energy Supply	Energy Supply and Generation	Use of Renewable Energy Sources
Energy Supply	Energy Supply and Generation	More Efficient Use of Fuels
Energy Supply	Energy Supply and Generation	Decentralized and Near to Consumer Energy Distribution System

Reducing Heating and Cooling Oriented Energy Consumption

The design and thermal integrity (e.g., insulation levels) of buildings are essential for the amount of energy intensity (energy/m^2) needed for heating and cooling. Reducing the energy associated with heating has been a strong focus in northern European countries, but mid-attitude countries have to attempt a design a balance between heating and cooling energy demands. The influence of building technology on the energy used for space heating is huge: a Passive-house standard requires that energy use for space heating be no more than 15 kWh/m^2 floor area per year; for low-energy houses the corresponding number is around 50 kWh/m^2, whereas poor thermal insulation may cause energy use for space heating of 200–400 kWh/m^2 in mid-European latitudes[3] (GEA, 2012).

DEVELOPMENT TYPE

Next to the energy characteristics of an individual building, also the mix of building types and their density are important determinants of urban energy use. The specificities of the urban built environment are usually a large existing stock, which requires renovation and maintenance, and new buildings in growing cities. Residential floor space per capita is known to be strongly correlated with income (e.g., Schipper, 2004, p. 529; Hu et al., 2010, p. 301) which impact directly energy consumption rates in cities. Newton et al. (2000) evaluated and modeled the energy performance of two 'typical' dwelling types – detached houses and apartments – across a range of climatic zones in Australia. Two main conclusions were drawn: (1) annual heating and cooling energy and embodied energy per unit area were similar for apartments and detached houses; (2) per person, however, the lifecycle energy of apartments was significantly less (10–30%) than that of detached houses in all circumstances, because the area occupied per person was much less. Norman et al. (2006) used a lifecycle analysis approach to assess residential energy use and GHG emissions, contrasting 'typical' inner-urban, high-density and outer-urban, low-density residential developments in Toronto. They found that the energy embodied in the buildings themselves was 1.5 times higher in low-density areas than that in high-density areas on a per capita basis, but was 1.25 times higher in high-density areas than that in low-density areas on a per unit living area basis.

Urban Morphology- high Density and Compactness

Salat and Morterol (2006) compared 18th century, 19th century, and modernist urban areas in Paris, assessing five factors in relation to CO_2 emissions for heating: (1) the efficiency of urban form in relation to compactness; (2) a building's envelope performance; (3) heating equipment type, age, and efficiency; (4) inhabitant behavior; and (5) type of energy used. Salat and Morterol (2006) asserted that an efficiency factor of up to 20 could be achieved from the worst-performing to the best-performing urban morphology by taking these five factors into account. Salat and Guesne (2008) investigated a greater range of morphologies in Paris and found that when considering heating energy, the less dense the area, the greater the energy required for heating (see also Ratti et al., 2005, p. 762). Urbanization patterns affect the extent and location of urban activities and impact the accompanying choice of infrastructures. Newton (2000) summarized key alternative urban forms or 'archetypal urban geometries,' namely the dispersed city, the compact city, the edge city, the corridor city, and the fringe city. The merits of dispersed and compact cities ('suburban spread' versus 'urban densification') have been debated since the 19th century and a strong divide exists between the 'de-centrist' (the dispersed city model) and 'centrist' (the compact city model) advocates (Brehny, 1986).

Nonetheless, one the most important characteristic of cities is density. Overall, a certain density threshold is the most important necessary (although not sufficient) condition to allow efficient and economically viable public transit. In addition, in a dense environment distribution networks are shorter, infrastructure is more compact, and district-heating and -cooling systems become feasible. Unconventional energy sources, such as sewage and waste heat, are also more accessible. High density may thus help curb urban energy use (Rickaby, 1991, p. 153; Banister, 1992; Ewing and Cervero, 2001, p. 87; Holden & Norland, 2005, p. 2145).

Another important influence of density is at the personal consumption level. Apartment size per person tends to decrease with population density. More compact cities, however, may require special management to avoid the ill-effects of congestion and higher concentrations of local pollution (e.g., see Jenks et al., 1996). Urban heat island effects, for instance, may be exacerbated in dense urban cores. There may be a trade-off between the transport energy savings achieved with higher urban density versus the higher energy use of high-rise buildings. There are also trade-offs between urban density, dwelling type, block size, and the ecosystem services provided by vegetation. Both theoretically and empirically, it is by no means clear that there is an ideal urban form and morphology that can maximize energy performance and satisfy all other sustainability criteria.

Bringing Locations and Activities Closer (Mixed Use Concept)

Most importantly, a compact city brings the location of urban activities closer. In the context of transportation, from cross-city comparisons it is well established that higher urban densities are associated with less automobile dependency and thus less transport energy demand per capita (Newman and Kenworthy, 1989, p. 24; Kenworthy and Newman, 1990, p. 344; Newman and Kenworthy, 1991; Brown et al., 2008; Kennedy et al., 2009, p. 7297). Mixed land uses and concepts of self-containment are important in reducing energy use in transport. Nevertheless, local jobs and local facilities must be suitable for local residents, otherwise long-distance, energy-intensive movements will continue (Banister et al., 1997, p. 125). This coordination of land-use and transportation policies is termed transit-oriented development. The idea of location efficiency emphasizes the accessibility of opportunities, rather than how mobile one must be to find them (Doi et al., 2008, p. 1098); this is a central concept in recent approaches to transit-oriented development and other forms of sustainable urban development.

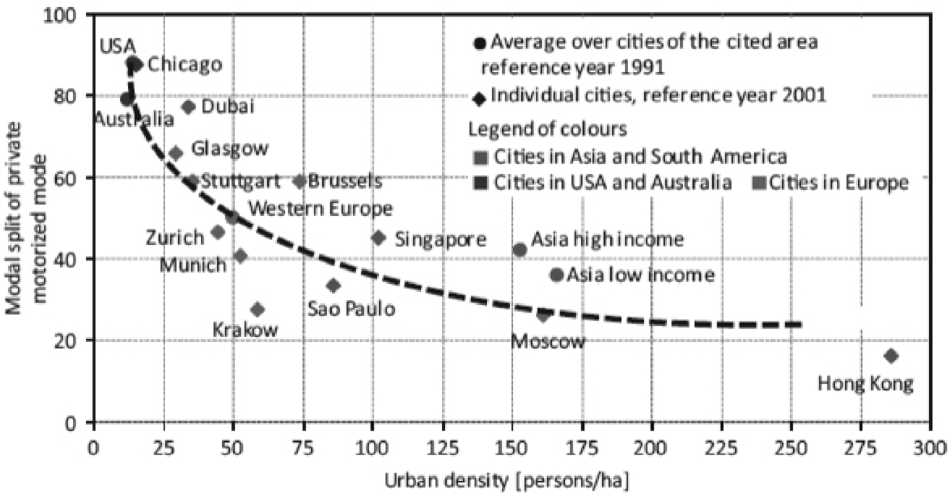

Fig. 6. Relation of Urban Density and Share of Private Motorized Transport Modes (Calculated form Total Mobility, Including Non-motorized Modes) for Individual Cities and Regional Average Cities.

(Kentworthy et al., 1999; Kentworthy and Laube, 2001; Vivier, 2006)

Also, urban density is an indicator of potential energy savings, especially in transportation. If infrastructure is inadequate to support the volume of traffic flow the resulting congestion can lead to higher energy use, even in high-density, built-up areas. For energy efficiency potentials of urban densities to be realized, a chain of interdependent, appropriate infrastructure, technical, and consumption decisions must be made. The correct level of public transit infrastructure requires large up-front investment and maintenance, from light rail to subways, trams, or dedicated bus routes. Adopting public transit also requires appropriate consumer behavior. In many North American cities, public transit is associated with lower economic status, and thus avoided by most people who can afford to drive, which reinforces the initial perception (Dhakal, 2004; 2009, p. 4208).

Urban Energy Supply System

Another important energy implication of the urban form is the choice of urban energy-supply systems. District-heating and cooling infrastructures, which allow large economies of scale and efficiency gains through cogeneration, are only possible when the density of demand is high enough to warrant the capital-intensive investment, unless such systems are mandated (and costs added to land prices). Compact urban form may also play a role in the energy used for buildings. Apartment buildings generate economies of scale compared to single-family homes, but apartment buildings may compromise decentralized low-energy design practices, such as natural lighting, ventilation, and decentralized use of PVs (GEA, 2012).

CONCLUSION AND URBAN ENERGY EFFICIENCY STRATEGIES

Energy is essential for human development and energy systems such as urban energy systems are a crucial entry point for addressing the most pressing global challenges of the 21st century. A major transformation is therefore required to address the existing challenges and to avoid potentially catastrophic future consequences for human and planetary systems. The policy challenge is to accelerate, amplify and help make the implementation of these changes possible, widespread and affordable. Initial experience suggests that many of these changes are affordable, although they may be capital intensive and require high upfront investments. However, in general they have lower long-term costs that offset many of the up-front added investment requirements. Many of these innovations also lead to benefits in other areas such as equity and poverty, economic development, energy security, improved health, climate change mitigation, and ecosystem protection. Based on the previous studies, a wide and comprehensive range of urban energy efficiency strategies is classified and provided as the following tables. These strategy measures are categorized in 5 groups according to the main urban energy key drivers mentioned in previous sections. These include strategies in the following categories:

- Natural Environment
- Socio-economic Characteristics
- National/International Urban Functions
- Urban Form (Urban Planning and Design)
- Energy Systems

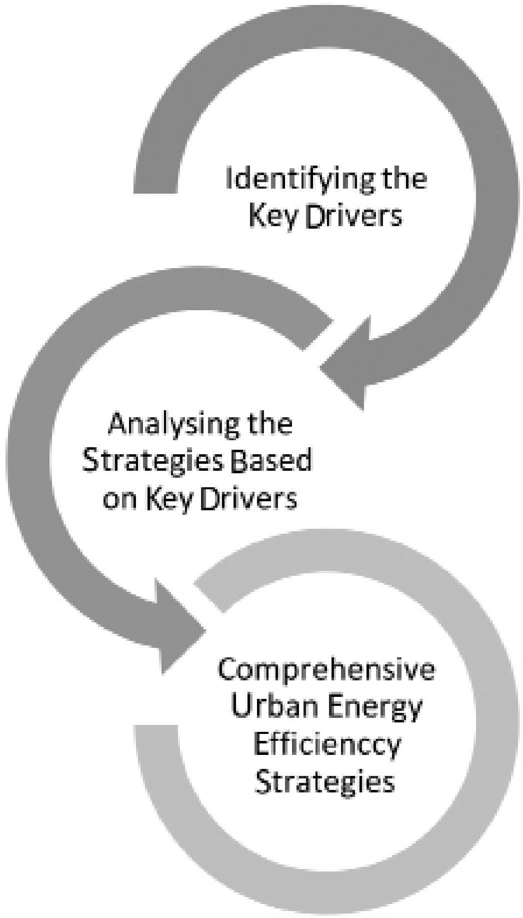

Table 2. Strategies for Energy Efficient Urban Development

Main Urban Energy Drivers			Policy Measures
Natural Environment			• Co-Planning & Design, through Considering Environmental Specifications in Planning and Design Procedure (I.E., Solar Energy, Wind Direction, Heating and Cooling Needs, Topography and etc.)
Socio Economic Characteristics			• Enhancing Culture of Conservation am ong Consumers and Firms. And Consideration of Social Norms in Planning and Design Process • Individual and Public Awareness. and Considering Community and Social Capacities to Adapt to Changes • Changes in Culture, Lifestyles and Values are Required through Effective Participation
National/International Urban Functions			• High Level Policy Making on Future Oriented Impacts of Urban Functions on Energy in Frame of Short, Medium and Long Term Plans
Urban Form (Planning and Design)	Compact Structure and Layout of the Building		• Optimization of The A(Area)/V(Volume) Ratio (Smaller Heat Transfer Envelope Area in Relation to the Building Volume) • Compressed Design through Building Typology • Optimization of the Length of the Building Body • Optimization of the Depth of the Building • Optimization of the Number of Floors • Optimizing the Roof Shape / Roof Pitch
	Topography		• Utilizing the Topographical Conditions to Minimize the Thermal Energy Consumption • Wind Protection and etc.
	Passive Use of Solar Energy		• Building Orientation (Mostly to the South) • Considering the South Facades as one of the Most Important Energy Absorption Potentials • Designing South-Facing Roof Surfaces • Avoid Shading by Neighboring Buildings / Vegetation
	Transport-Oriented	Avoiding Traffic	• Enhancing Mixed Use Development of Urban Activities • Planning for Short Distances to Reduce Private Vehicle Mile Traveled • Minimize Traffic Areas (Less Surfaces For Roads And Streets in Planning)
		Expansion of Public Transport, Walking and Cycling	• Prioritizing Public Transport in Road Space • Strengthening of Cycling and Walking
	Buildings	Building Technology/ Heat Protection	• Structural Thermal Insulation in Existing Buildings • Use of Modern Heating Technology for Existing Buildings • Use of Ventilation Systems in Existing Buildings
		Building Standards	• Construction of Energy-Efficient Houses
Energy Systems	Transformation		• Significantly Larger Investment in Energy Efficiency Improvements • Standards and Regulations for Building Codes Heating and Cooling Appliances, Fuel Economy, and Industrial Energy Management
	Renewable Energies		• Integrating Renewable Energies into the Energy Systems
	Modern Energy and Technologies		• Using Smart-Systems with Advanced Sensing and Control Capacities

ENDNOTE

1. International bunker fuels are an important exception that, by simple definition, are excluded in national energy-use balances and the resulting emission inventories.

2. A working paper on urban form and morphology contains a more extended discussion and is accessible at www.globalenergyassessment.org.

3. See http://energieberatung.ibs-hlk.de/

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