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The Reduction of the Hydrocarbon Energy Supply and the Development of an Alternative City Design Approach

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ABSTRACT

Currently we live in a society high in energy consumption. In 2005, total worldwide energy consumption was 500 Exajouls with about 90% derived from the combustion of hydrocarbons. We demand this enormous volume of energy not only to feed and heat ourselves, but also to maintain the overall standard of living currently available in our great cities. This uncontrollable demand for energy is directly affecting its supply. At the moment about forty percent of world's energy demand is fulfilled by oil, which energy experts estimate has either already reached its peak production or will be at the peak within the next 5 to 10 years.

In this context, the purpose of this paper is to identify an alternative city design approach, which will be required to prepare our urban environment appropriately for the period, when the current energy system will be forced to transform into a renewable energy arrangement due to a dramatic and significant reduction in the hydrocarbon energy supply. The paper examines progressive development in city design approaches from the firewood to the coal age and then to the oil era. Then the paper analyses the nature of the alternative energy sources and their effects on the performance of our current city models. At the end the paper illustrates an alternative city design approach based on recent developments in hydrogen fuel cell research, intended to combat any dramatic fall in our quality of life beyond the oil era.

KEYWORDS: Hydrocarbon, city design, quality of life.

1. INTRODUCTION

The global forces of urban change provide the context for cities to act appropriately. Over the past few years the world's large cities have been experiencing increasing resource scarcity issues like rising oil prices and limited access to renewable energy sources. Energy of all sorts was once hugely abundant, making possible the creation of a society high in energy consumption. According to the US Department of Energy, this, in turn, has led to a 47% rise in global energy consumption in the past 20 years alone. In 2005, total worldwide energy

consumption was 500 Exajouls with about 90% derived from the combustion of hydrocarbons (EIA, 2006). We demand this enormous volume of energy not only to feed and heat ourselves, but also to maintain the overall standard of living currently available in our great cities. The uncontrollable demand for energy is directly affecting its supply. At the moment about forty percent of world's energy demand is fulfilled by oil, which energy experts estimate has either already reached to its peak production or will be at the peak within the next 5 to 10 years. This is rapidly removing the energy-abundant world we are familiar with and creating in its place a new energy order as a global force. The issue then arises as to how cities are going to react to this emerging global force.

In this context, the purpose of this paper is to identify the influence of various traditional energy sources on our city making process, and then to explore how these cities would be able to transform their urban environment appropriately for the period when the current energy system will be forced to transform into a renewable energy arrangement due to a dramatic and significant reduction in the hydrocarbon energy supply. Firstly, the paper examines the progressive development in city design approaches from the firewood to the coal age and then to the oil era. Secondly, the paper analyses the nature of the alternative energy sources and their effects on the performance of our current city models. Thirdly, the paper illustrates an alternative city design approach based on recent developments in hydrogen fuel cell research, intended to combat any dramatic fall in our quality of life beyond the oil era.

2. ENERGY AND URBAN FORM

In the early days of human civilisation small groups of mobile people relied on their physical strength and energy to collect food by hunting wild animals. When these tribal groups started to settle permanently in small settlements they primarily relied on neighbouring forests to receive supplies of firewood. The settlers had to locate and design permanent settlements with safe and convenient fuel sources. In this way energy consciousness became one of the important factors in determining early urban forms.

As energy started to play an important role in urban communities, early settlers were active in reducing any possible gap between the demand and supply of fuel. The earth was covered then with a high proportion of forested area. However, the world's agricultural development required continuous clearing of forests to plant more crops and additional crops supported a larger population with more demand for the wood fuel. Eventually when industrial activities started pressure on firewood was acute and people were desperate to find an alternative energy source to maintain improved urban conditions. At that stage coal was discovered and was the obvious alternative. The change of the energy source from wood to coal ultimately improved urban productivity dramatically and transferred the economic power base from the agriculture based rural areas to industry based urban areas. This shift in the energy base also assisted in generating the first generation industrial towns with a higher concentration of residential buildings around the industrial production, manufacturing and business centres.

Coal was abundant and its higher energy density made it far more economical than wood to produce, transport over long distances, and store. It ultimately completely outclassed wood as its energy counterpart when coal based combustion engine was able to convert the heat energy into mechanical energy to perform various tasks which in the past were used to be performed by either humans or animals.

Coal is a fossil fuel and contains carbon. During the early period of industrial revolution, the smoke generated from burning coals very quickly started to cover the skies of industrial cities with a high concentration of carbon dioxide. The inner city areas where most of the industries were located became very unhealthy to live. As a result the urban living pattern started to transform with the movement of wealthy people towards the city periphery. Until approximately 1850, almost all cities of the world were essentially very overcrowded pedestrian precincts, little more than 1.6 kilometres in radius (Vance, 1990). However, the introduction of coal based steam trains started to alter that compact urban form. The coal based trains allowed general working class people to stay further away from their work places where relatively clean air was available.

Ultimately the combustion-engine-based transport technology unleashed its maximum potential with the introduction of oil as its newest source of fuel. The gasoline engine with its greater power and range completely transformed the transportation sector by introducing high speed cars, trucks, buses, trains, planes and ships. These transport modes allowed people to live anywhere and work anywhere, and broke the traditional city limit of 4 to 5 kilometres. Urban settlements with around 11,000 square kilometres of area emerged as people were able to move easily up to 60 kilometres by car every day for regular work purposes (Dravitzki, 2007). New fuel technology in the transportation sector allowed to develop suburbs and began the age of urban sprawl.

3. THE NEW ENERGY ORDER

In 1901, the Spindletop Well near Beaumont, Texas, opened the enormously productive oil reserve in the Gulf Coast and helped to start the golden period of the oil era (Deffeyes, 2005). With the help of oil the age of the automobile was in full swing in the 50s and 60s. Cities like Los Angles, and including Auckland, Sydney, Melbourne in this part of the world became famous for their car culture, highways and traffic jams. At the same time, the sprawling suburbs and bedroom communities that the automobile culture encouraged started to enlarge the urban extent of these cities. To support the enlarged cityscape, the energy demand of these cities is increasing every year. At the same time, cities in the former developing countries like China and India have started to produce a wide range of goods for the international markets. This, in turn, has led to an unprecedented increase in global energy consumption. The table below shows top five oil consuming countries based on recently available data.

Table 1: Worldwide Oil Consumption

Rank	Country	Consumption (barrels/ day)	Year
1	United States	20,680,000	2007
2	China	7,578,000	2007
3	Japan	5,007,000	2007
4	Russia	2,858,000	2007
5	India	2,722,000	2007

Source: The CIA World Factbooks, 2008

Unfortunately, this trend is not going to reverse; instead, global energy demand will rise year by year. It is estimated by some energy experts that by 2035, the world will use more than twice as much energy as it does today. Demand for oil will jump from the current 80 million barrels a day to as much as 140 million barrels. While future energy demand is certain, it is not clear how long the current energy sources will be able fulfil this demand. The reality is that the supply of the hydrocarbon energy sources, ie. coal, gas and oil is not infinite. Someday, annual world crude oil production has to reach a peak and start to decline.

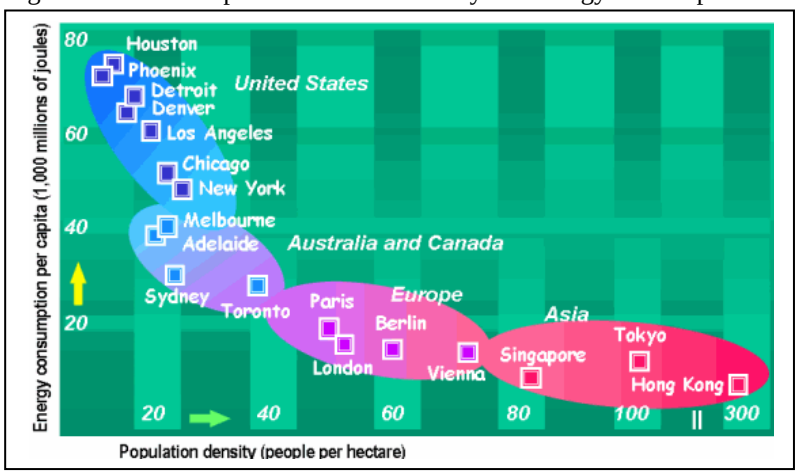
In 1969, M. King Hubbert, an American geologist, published predictions of future oil production. Hubbert predicted that the world's total oil reserve is 2.1 trillion barrels and the peak production is in the year 2000. However, this prediction has been challenged, and some experts using the US Geological Survey data, provided a more optimistic scenario with the peak in around 2036. The reserves of coal and gas are better than the oil reserve, but these reserves will be ultimately exhausted too. Due to increased electricity demand, cheap coal and gas fired power plants are growing in numbers in China and India.

These gloomy scenarios are making it clear that current hydrocarbon based energy order is on its way out. This is not only discussed by environmental scientists and activists, but also realised by giant energy corporations. The CEO of Royal Dutch Shell recently said, *"after 2015, easily accessible supplies of oil and gas probably will no longer keep up with demand"* (MfE, 2009). In this context, the search for less problematic forms of energy and more energy efficient technologies is the top priority for all players in the energy world, which sets the base for a new energy order.

Under the new order, the last remaining stock of oil most likely will be required for aviation and container shipping purposes, as technological conversion of these transport modes will be costly and time consuming. The situation would be different at the ground level, where giant solar panels, large wind farms, small scale geothermal and hydro power plants and distributed hydrogen fuel cells would be utilised to meet the energy demand. The question is whether this new energy infrastructure would be able to be accommodated appropriately within currently available suburban sprawl based city forms or not.

Today there are more than 400 cities with more than a million people, and 20 mega cities have 10 million or more residents (World Urbanization Prospects, 2008). Some of these massive cities are widely spread out with a low population density. At the same time, these cities support sprawl of suburbs. Suburbs depend on importing everything including electricity, water and food, these are also often isolated geographically from jobs, education, specialised retail and recreation facilities. These suburbs primarily accommodate low density housing and create a commuter culture. Accordingly, a direct relationship has been found between urban density and energy consumption. (refer Figure 1 below).

Figure1: Relationship between urban density and energy consumption



Source: Newman, P. and Kenworthy, J, 1999

There is no doubt that highly energy dependent cities will be hard hit by the coming decline in oil production, and suburbs will be hit even harder. Currently cities rely on centralised

electricity, water and food production, and waste disposal facilities which are typically located far away from cities living areas. Transportation of products between these facilities and consumers requires enormous volume of energy. Any shortage in energy supply will therefore ultimately affect the supply of electricity, water and food, and also waste disposal. At the same time, current cities and their living areas are not properly designed to accommodate the distributed and cost-effective small scale facilities of the new energy order. This will make the city situation more difficult, and as a whole, the quality of life will dramatically fall in many great cities. This sets the basis for a Plan B, ie. an alternative city design approach to combat any dramatic fall in city's quality of life beyond the oil era.

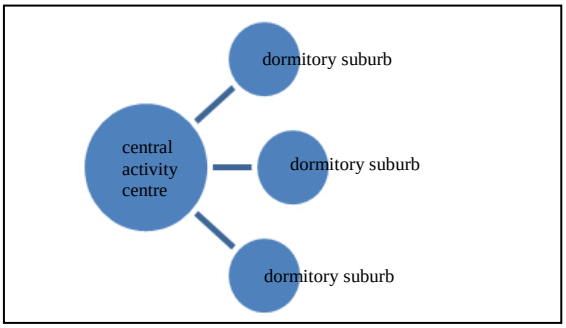
4. AN ALTERNATIVE CITY DESIGN APPROACH – REVITALISING NEIGHBOURHOODS

The alternative approach is nothing but a vision to transform and strengthen cities' neighbourhoods, so that ultimately these do not become slums like Peter Jackson's District 9. This approach is the Plan B to revitalise our neighbourhoods by allocating resources through a bottom-up process instead of a top-down process usually applied in the regional centre based planning. This approach is to prepare our cities for that period when hydrocarbon energy supply will be reduced significantly and a new energy order will take place.

This alternative city design approach is based on a self-sufficient neighbourhood concept, where each individual neighbourhood will be able to provide its inhabitants' living, working and playing facilities all together in the same place. Neighbourhoods will complement each other, but will not depend on each other, and collectively they will form a greater urban area or city.

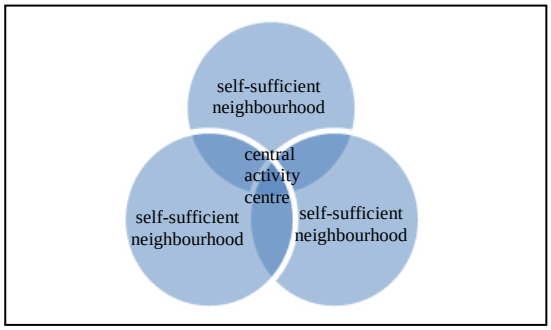
Some central activity centres appropriately distributed throughout the entire city will be still required to accommodate some specialised activities (ie. higher education, specialised retail, large scale sporting and musical performances etc.) including many blue and white colour jobs. Because bringing all these specialised activities and jobs at the neighbourhood level will not be economically feasible, the households at the neighbourhood level will instead be able to access their jobs, university classrooms, retail showrooms, large stadiums and concert facilities remotely effectively and efficiently through ultra-speed broadband network without leaving their houses. This will reduce their car travel demand significantly. At the same time a rapid and mass transit system (a combination of fuel cell or electric battery powered bus and train) will provide a combustion engine free transport mode between the neighbourhoods and between specialised activity centres and neighbourhoods.

Figure 2: Suburban sprawl based city



Source: The Author, 2009

Figure 3: Self-sufficient neighbourhood based city



Source: The Author, 2009

Under the Plan B or alternative design approach neighbourhoods will,

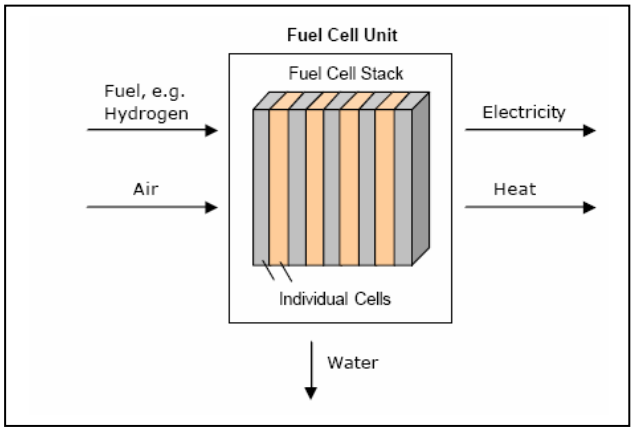
- rely on different distributed small-scale service facilities, ie. power plants, water tanks, vegetable gardens and recycling facilities;
- accommodate renewable energy sources, ie. wind, solar, hydrogen, bio fuel, geothermal and hydroelectricity;
- support the hi-tech achievements in the communication and entertainment sectors, ie. ultra fast broadband, 3d projection and virtual reality;
- promote energy conservation, reuse of water and recycle of waste;
- expect productivity increase at the neighbourhood level, neighbourhood self-sufficiency and less dependency on cars, larger centres, and highways and motorways;
- provide the opportunity to develop communal harmony and interaction through sharing various commonly owned assets (ie. distributed power generation facility etc.) including community facilities;
- encourage a mix in land uses at the neighbourhood level;
- include appropriate diversity in the housing density; and
- restrict inappropriate and abusive use of the natural and open space resources.

The alternative city design approach has been proposed to combat against the fuel crisis. Therefore, the search for an alternative and viable fuel source, and appropriate accommodation of this source within the urban form is one of the most vital components in this alternative city design approach. Accordingly, this paper primarily concentrates in this particular design component.

In our current cities, energy needs are overwhelmingly dependent on fossil fuels in the form of coal, gas and oil. Electricity generation and transport are particularly dependent on burning fossil fuels. However, under the alternative city design approach, cities will be able to accommodate alternative energy sources, ie. renewable sources to generate electricity at the neighbourhood level, that means, at the door front of the consumers. This will be able to reduce electricity transmission cost and system loss significantly. To make this happen, an alternative land use policy will be required to allow the appropriate level of land use mix at the residential neighbourhood level. At the same time, innovative subdivision design and land ownership could be utilised to establish medium sized and jointly owned blocks with an appropriate buffer as the operational base for small utility facilities. In this respect, a comprehensive design, ie. subdivision and land use design should be considered together, which smart developers are currently applying anyway.

In locating the electricity generation facility at the neighbourhood level, reverse sensitivity, visual and privacy effects may arise and may compromise the viability of certain operations like wind turbines and solar farms. In this respect, hydrogen fuel cells (commonly known as fuel cells) would be the ideal candidate. Fuel cells generate electricity from a simple electrochemical reaction in which oxygen and hydrogen combine to form water. There are several different types of fuel cell, but they are all based on a central design and they all use hydrogen as the fuel to produce electricity. The hydrogen atom is the smallest, simplest and the most ancient matter, which was created immediately after the explosive birth of the universe. Hydrogen forms 75% of the mass in the universe, but it is very hard to find in its pure form. The technology to use hydrogen as a fuel in the fuel cell was originally invented in early 1839. However, the fuel cell's capacity improvement process has gained serious momentum in the recent years, because this 150 year old energy technology is clean, quiet, and nearly three times as energy efficient as even the best internal combustion engine.

Figure 4: A typical fuel cell system



Source: Fuel Cell Today, 2009

Figure 5: Fuel cell in a residential house

Source: Panasonic, 2009

The electricity produced from the fuel cell can be used for all types of activities, from houses to transport modes (cars, buses etc.). Heat and water are the by-products from the chemical reaction in the fuel cell. The by-product heat can be used to keep houses warm. There is significant potential for small stationary fuel cell units in the residential housing sector (Fuel Cell Today, 2009). The power output from such a cell would be below 10KW. The cell could be used to provide both power and heat to individual houses or groups of houses, and could be designed to meet all energy requirements of the households, or only the base load, with peak demands covered in another way.

The Japanese electronics giant Panasonic recently developed a show house in Tokyo, which virtually ensures zero CO_2 emissions throughout the entire house. The house utilises a combination of fuel cells, solar power generator and accumulator batteries to generate and store energy within the house level. Ultimately a series of this type of house would be able to create a neighbourhood in the line of Plan B.

The uniqueness of the fuel cell and the vision of an alternative city design approach are clearly supported and illustrated by the American author Paul Roberts in this way:

> *" Ultimately, fuel cell may provide the foundation not simply for a new mobility, but for an entirely new energy economy. In place of our sprawling and inefficient hodgepodge of pipelines, refineries, and polluting power plants, we would have thousands of interconnected yet independent Microsystems, each powered by a mix of alternative fuels and technologies, including fuel cells, and each generating energy cleanly, cheaply, and locally. Equipped with a backyard or basement fuel cell system, consumers and businesses could achieve a kind of energy independence, fuelling their cars and powering their lights and machinery without having to worry about rolling blackouts, manipulative power traders, or monopolistic utilities. After centuries of an increasingly centralized energy economy, controlled by a tiny elite of corporations and investors and protected by government, energy might again become a very local matter."*

(Roberts, 2004).

5. CONCLUSION

The intention of this paper is not only to discuss an alternative city design approach, but also to raise awareness in respect of the future of our cities. The design approach which is discussed here is obviously based on a number of underlying sustainable design principles, but this approach should not be considered only from an environmental response perspective. It needs to be considered primarily from a reality perspective based on an undeniable truth about the decline of earth's oil reserve. Again, the loss of quality of life beyond the oil era may not be equally applicable for all cities, as some cities are already managing their growth in a sustainable way and are not entirely dependent on the car culture like some North American cities. However, this does not mean that any urban catastrophe in some parts of the world would not be able to affect these well managed cities. Urbanisation in different parts of the world is currently well integrated with entire world's economic, social and environmental conditions. In the current age of globalization, cities in different countries are tied together financially and commercially. The cities are physically separated, but they are not isolated from each other. The effects of the declining petroleum economy on various cities might not appear immediately as our backyard problem, if we are the lucky inhabitants of a currently available sustainable city, but ultimately we would not be able to escape from these effects. An alternative city design approach needs appropriate consideration, because ultimately it will be a smart choice for everybody's future.

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