# Driving Forces for Energy Demand



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Nicolai Bratt Christina Johansen Maninder pal Singh

## Table of Contents

**1. Introduction** **3**

**2. Driving Forces for Energy Demand** **4**

2.1 Economic Growth 6

2.1.1 Residential and Commercial Demand 7

2.1.2 Transportation Demand 10

2.1.3 Industry Demand 12

2.1.4 Power Generation 13

2.2 Energy Efficiency 13

**3. Policy and Pricing Implications** **17**

3.1 Climate Change is Real 18

3.2 Status Quo – No Man Made Global Warming 23

**4. Conclusion** **27**

**5. Works Cited** **28**

## Table of Graphs & Figures

2-1 Correlation of GDP and Energy Demand 1980 – 2030E 4

2-2 Energy Consumption vs. GDP (2004 in 2000 USD) 5

2-3 The Energy Ladder 6

2-4 The Energy Ladder S-Curve 6

2-5 Global Energy Demand Drivers 7

2-6 Final Energy Consumption by End Uses in India 2005 8

2-7 Projections of Rate of Appliance Diffusion 8

2-8 Growth in Vehicle Ownership 10

2-9 Total distances traveled by car, bus, train and aircraft, in various regions of the world 11

2-10 Global Industrial Energy Demand by Sector and Area 12

2-11 Growth in Electricity Usage 13

2-12 Global Energy Efficiency Development 14

3-1 Correlation Between International Oil Price Index and Domestic End-Use Energy Price Index17

3-2 Evolution of Size and Price in Various Carbon Markets 20

3-3 Cost per KW/h, US baseload plants under various CO2 cost assumptions 22

3-4 UK Growth Vs. Aggreagate Air Pollution Emissions % (1970 – 2001) 24

## 1. Introduction

The future of energy is directly linked to the future well-being and prosperity of the world's people. (ExxonMobil, 2009). The growth in demand for energy is closely linked to economic growth and the efficient use of energy. The sharp increase in energy demand seen from about 2000 can be attributed to the rapid growth of China, India and other emerging economies (Benthem & Romani, 2009). This energy demand growth has been a side effect of large populations, better living conditions and improved qualities of life in particular in Asia. At the same time, there are still 1.5 billion people, a quarter of the world's population, who lack access to electricity (ExxonMobil, 2009). By providing reliable and affordable energy, policy makers can help spur economic growth to help lift people out of extreme poverty.

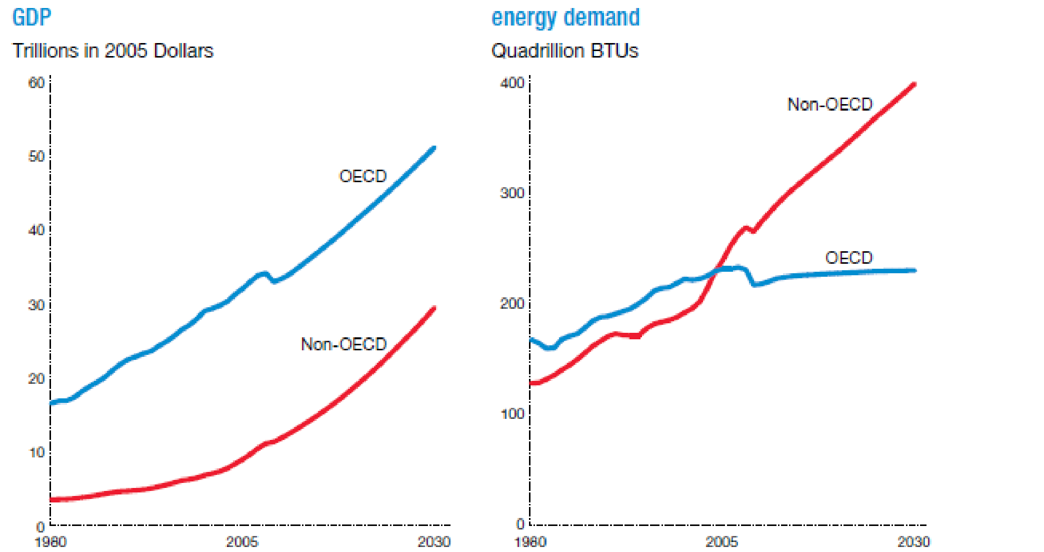
As a result of increased efficiency in the use of energy as an economy reaches a certain level of development, energy demand generally grows according to an S-shaped curve (Benthem & Romani, 2009) For policymakers, it is essential that the decrease in energy intensity (per unit of GDP) that creates the top part of the s-slope starts as early as possible to reduce pressure on energy supplies.

The increasingly controversial nature of CO2 emissions creates a range of implications for policymakers. On the one hand fossil fuels are a source of reliable and fairly cheap energy, on the other hand, the combustion of fossil fuels leads to emissions of CO2 and a range of pollutants that are harmful to the environment. Also, while it has been shown that demand is sensitive to price in the long term, it is even more sensitive to income, so that to be able to reduce CO2 emissions in the developed world while allowing for economic development in the developing world, policy with regards to pricing and energy efficiency will have to be highly differentiated. Such a differentiation may have consequences for the economies in the developed world with negative effects on employment rates and economic growth. Such negative effects are unlikely to be tolerated by voters in the long term.

## 2. Driving Forces for Energy Demand

EIA and IEA uses three major input assumptions for energy demand: economic growth, population, and energy policies. (National Petroleum Council: Raymond, 2007). For forecasting and comparison purposes, economic growth is shown through Gross Domestic Product (GDP) and the effect of energy policy can for example be shown through the change in the efficiency in the use of energy. GDP provides a measure for the change in the demand for energy services reflecting population growth, increased ownership levels of electric household appliances, bigger houses, more personal travel by car, and other factors which drive up energy use (Geller, Philip, Rosenfeld, Satoshi, & Fridtjof, 2006). Energy efficiency on the other hand measures the effects of the combined effects of technological advancement, education of consumers, and policy initiatives (National Petroleum Council: Raymond, 2007) on the amount of energy used to provide the same level of energy service. As can be seen in 2-1, the correlation between energy demand and growth in GDP has been very strong for both OECD and non-OECD

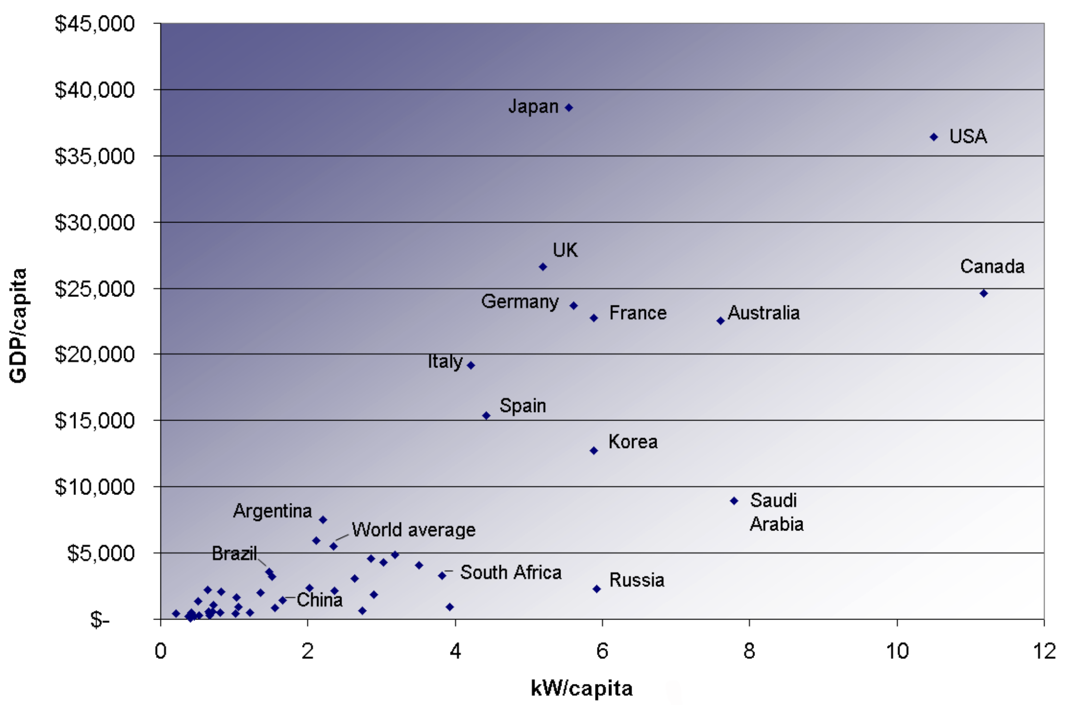
**2-1 Correlation of GDP and Energy Demand 1980 – 2030E**




**(ExxonMobil, 2009)**

countries. However, as can be seen by the lower slope of the energy demand graph for OECD countries, the relationship is less strong for OECD than non-OECD countries. This is a result of improvements in energy efficiencies in these countries. Energy efficiency improvement has been an important phenomenon in the global energy balance over the past 30 years. Without energy efficiency improvements, the OECD nations would have used approximately 49% more energy than was actually consumed as of 1998 (Geller, Philip, Rosenfeld, Satoshi, & Fridtjof, 2006). However, even if the slope of the Non-OECD countries is much lower than OECD countries, the energy usage per capita and energy intensity per capita is still much larger in developed countries. As seen in figure 2-2 France's GDP per capita was about 10 times that of China in 2004 while Energy usage is three times. This shows both the massive difference in energy consumption and the more efficient use of energy as measured towards GDP. Many developing countries are just reaching the point where individual wealth and energy consumption is starting to accelerate. For example, while the number of cars in China more than doubled between 2000 and 2006, there is still only one car for every 40 people whereas in the United States there is one car for every two people (National Petroleum Council: Raymond, 2007).

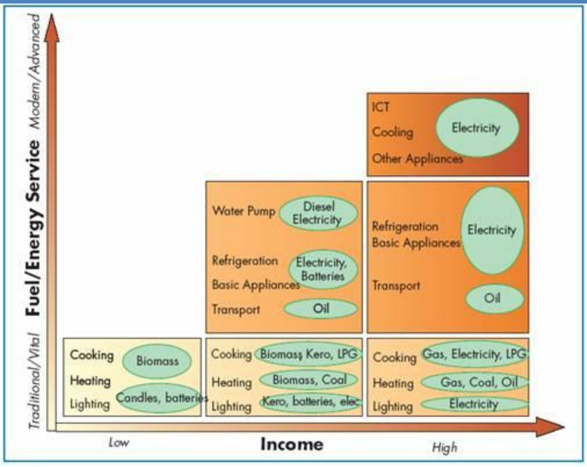
**2-2 Energy Consumption vs. GDP (2004 in 2000 USD)**




(Mierlo, 2007)

## 2.1 Economic Growth

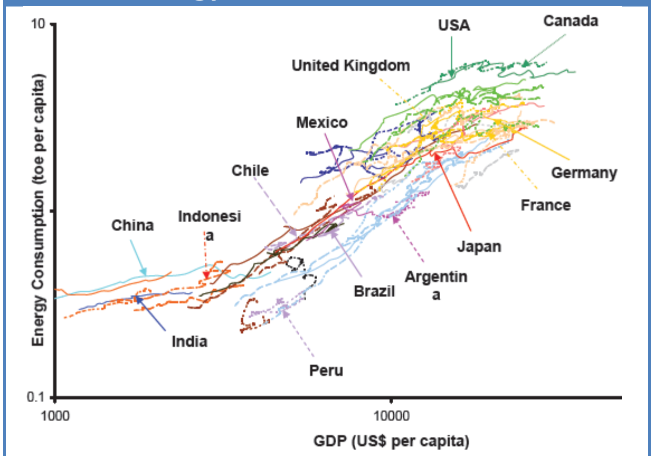
**2-3 The Energy Ladder**




(The Baker Institute, 2009)

The sharp increase in energy demand observed at the beginning of the new millennium was mostly attributed to the rapid growth of China, India and other emerging economies (Benthem & Romani, 2009). This rapid growth in energy demand showed how crucial energy is as less developed economies, often based on agriculture, gradually become industrial economies. During this process the energy intensity of each additional unit of output increases (Benthem & Romani, 2009). This process of development has often been called the climb up the energy ladder. Industrialized countries followed similar paths in the process of their development (Benthem & Romani, 2009). The energy ladder climb involves economic growth shown through rising incomes, which allows for a change in energy sources from dirty sources like biomass, candles and similar to electricity and natural gas. Along the climb, the use of energy also expands to new uses such as heating/cooling or transportation, explaining the rapid growth in the intensity of energy usage. As a result, highly developed countries end up with very high energy intensities compared with developing nations. Figure 2-4 shows how the energy ladder broadly creates an s-curve along the economic development of the countries. The s shape of the curve is a result of when economies reach a certain

**2-4 The Energy Ladder S-Curve**

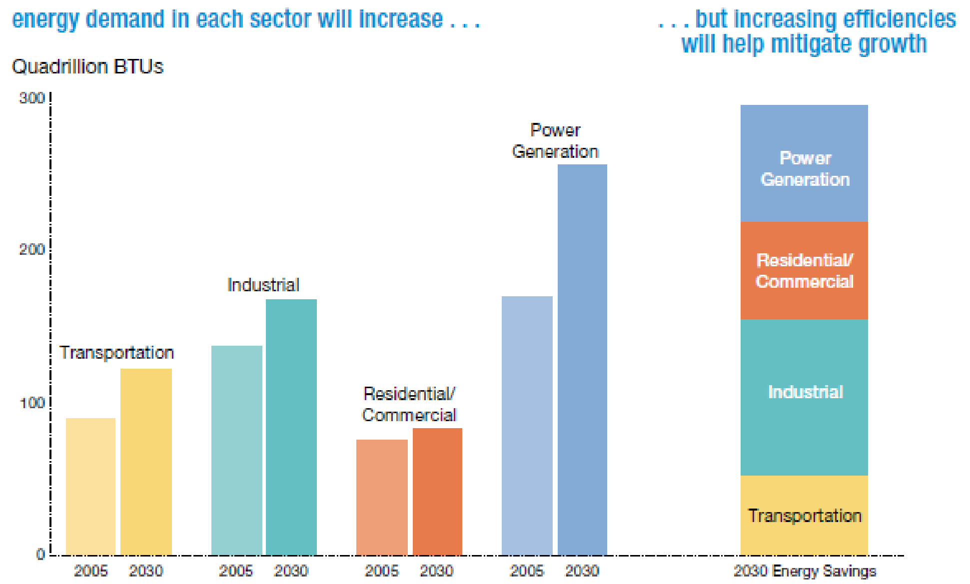



(Romani, Soldatos, & Benthem, 2006)

scale, the intensity of energy usage falls and growth slows, reducing the slope of the curve (Romani, Soldatos, & Benthem, 2006).

Energy usage in relation to economic growth can be broadly divided into four categories. Residential/commercial usage, which increases as people move towards cleaner energies for cooking, cleaning etc and further amenities like refrigerators, TVs etc. Transportation, which increases as societies become increasingly motorized. Industrial energy, related to production of goods and power generation needed to produce the electricity to power everything. The relative size of the four energy drivers is shown in Graph 2-5 in addition to the expected effect of increased energy efficiency on expected future growth.

**2-5 Global Energy Demand Drivers**

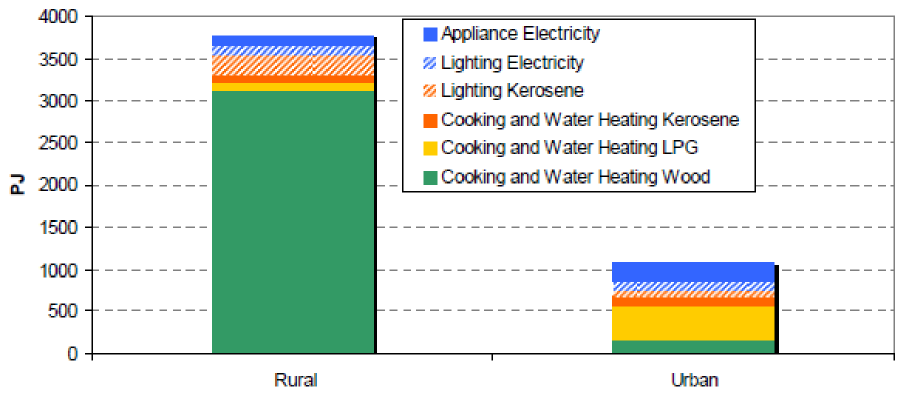



**(ExxonMobil, 2009)**

### 2.1.1 Residential and Commercial Demand

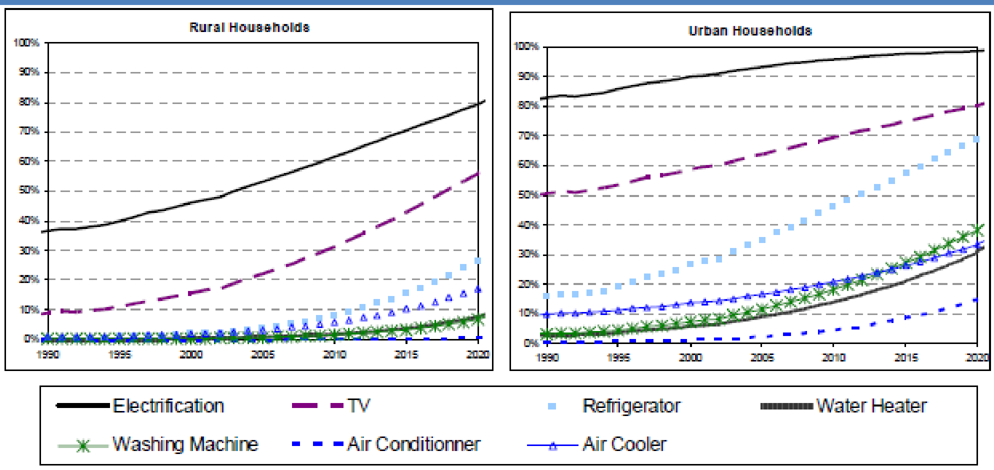
Worldwide, households consume about a third of all end-use energy. In countries with a temperate climate, more than half of this energy is typically used for heating (IEA, 2004). However, residential energy provides numerous services associated with household living, including space cooling, water heating, cooking, refrigeration, lighting, and the powering of a wide variety of other appliances. Energy demand is shaped by a variety of factors, including location (in both geographic location and urban vs. rural) and climate. In developing countries such as India, it is important to divide households into rural and urban locales due to the different energy consumption patterns found in these locations. (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). Although space cooling currently is a less important energy use than heating, it is growing rapidly both in high-income countries and in emerging economies such as India and China (Isaac & Vuuren, 2009). Energy consumption in the residential sector is closely linked to the urbanization rate. Urban households tend to have higher levels of energy needs and therefore, the migration of rural population towards urban centres increases the level of energy use. In addition, other factors, such as the increase in housing space represents a major driver of energy demand (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). The effect of urbanization in developing countries can be seen in graph 2-6 where the Indian experience shows how the use of wood for cooking and heating falls dramatically while electricity and LPG increases in importance.

2-6 Final Energy Consumption by End Uses in India 2005




(Can, Letschert, McNeil, Zhou, & Sathaye, 2009)

**2-7 Projections of Rate of Appliance Diffusion**




**(Can, Letschert, McNeil, Zhou, & Sathaye, 2009)**

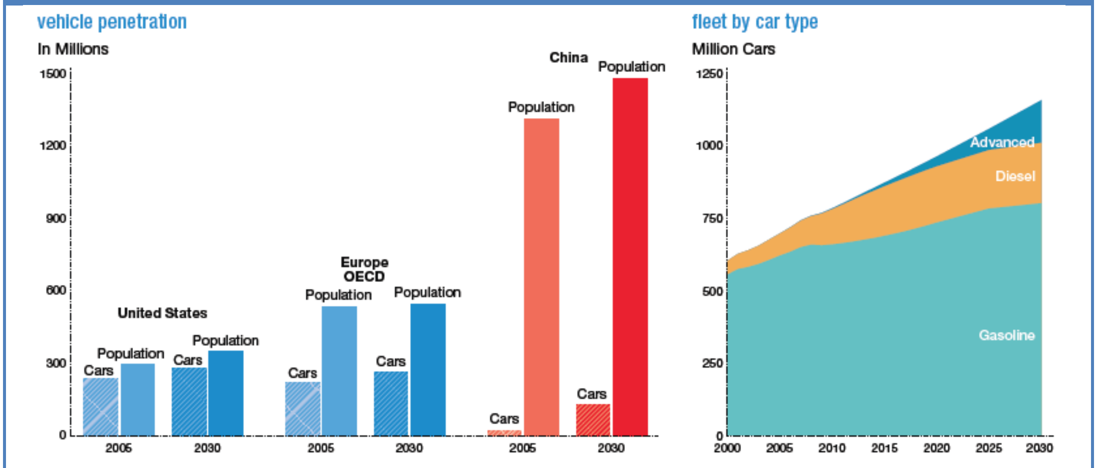
The substantial difference of final energy use between urban and rural areas is due to the fact that rural households use much more inefficient fuels, such as fuel wood for cooking and kerosene for lighting. Hence, their requirement to provide equivalent energy services than urban households is much higher. In addition, as seen in 2-7, other factors such as electrification and the resulting TV, washing machine, refrigerator, water heater, air conditioner etc ownership increases rapidly. This is a transformation similar to that developed world has already been through.

The commercial sector consists of businesses, institutions, and organizations that provide services. The sector encompasses many different types of buildings and a wide range of activities and energy-related services. Examples of commercial sector facilities include schools, stores, correctional institutions, restaurants, hotels, hospitals, museums, office buildings, banks, and sports arenas. Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial energy use. Economic trends and population growth drive commercial sector activity and the resulting energy use (EIA, 2009). The need for services (health, education, financial, and government) increases as populations increase. Economic growth also determines the degree to which additional activities are offered and utilized in the commercial sector. Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; for office and retail space to house and service new and expanding businesses; and for cultural and leisure space such as theatres, galleries, and arenas. In the commercial sector, as in the residential sector, energy use per capita in the non-OECD countries is much lower than in the OECD countries (EIA, 2009). Slow population growth in most of the OECD nations contributes to slower anticipated rates of increase in commercial energy demand. In addition, continued efficiency improvements moderate the growth of energy demand over time, as energy-using equipment is replaced with newer, more efficient stock. Conversely, continued economic growth is expected to include growth in business activity, with its associated energy use, in areas such as retail and wholesale trade and business, financial services, and leisure services (EIA, 2009). In the non-OECD nations, economic activity and commerce are expected to increase rapidly, fuelling additional demand for energy in the service sectors. Population growth is also expected to be more rapid than in the OECD countries, which mean increases in the need for education, health care, and social services and the energy required to provide them. The energy needed to fuel growth in commercial buildings will be substantial, with total delivered commercial energy use among the non-OECD nations projected to grow by 2.7 percent per year from 2006 to 2030 (EIA, 2009).

### 2.1.2 Transportation Demand

Energy use in the transportation sector includes the energy consumed in moving people and goods by road, rail, air, water, and pipeline. The road transport component includes light-duty vehicles, such as automobiles, sport utility vehicles, minivans, small trucks, and motorbikes, as well as heavy-duty vehicles, such as large trucks used for moving freight and buses for passenger travel.

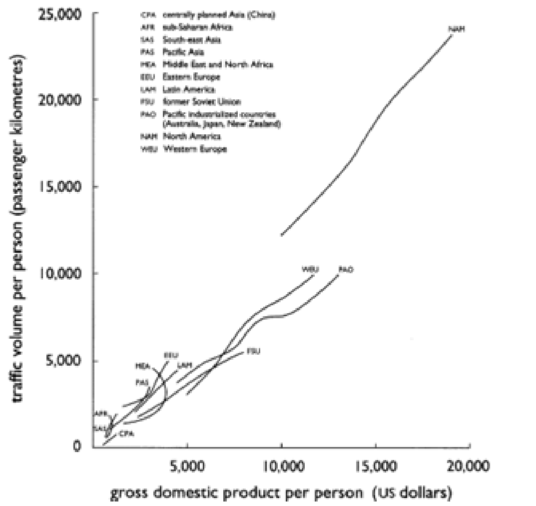
**2-8 Growth in Vehicle Ownership**




(ExxonMobil, 2009)

Growth rates for economic activity and population are the key factors for transportation sector energy demand. Economic growth spurs increases in industrial output, which requires the movement of raw materials to manufacturing sites, as well as the movement of manufactured goods to end users (EIA, 2009). For both the non-OECD and OECD economies, steadily increasing demand for personal travel, as related to vehicle ownership and distance travelled is a primary factor underlying expected increases in energy demand for transportation. As with energy use in buildings, there is an expected continuous year-on-year growth in the energy demanded for transportation usage. There are expectations for massive growth as the developing world starts to acquire cars and drive them over further distances. 2-8 shows the massive growth of vehicle ownership that can be expected if the Chinese are to own cars on the same level as Europeans and Americans. Also, as shown in Graph 2-9 the distance the ever growing number of vehicles can be expected to be driven is increasing (Barrett, Lowea, Oreszczyna, & Steadmana, 2008).

**2-9 Total distances traveled by car, bus, train and aircraft, in various regions of the world**



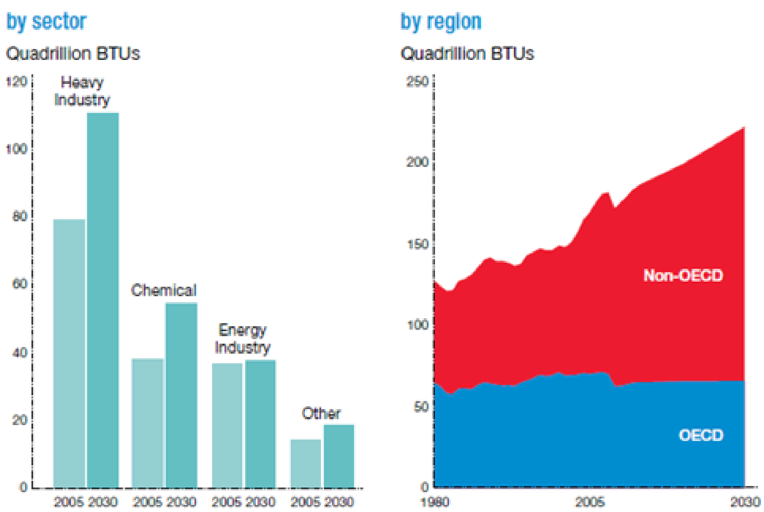

(Barrett, Lowea, Oreszczyna, & Steadmana, 2008)

Changes in patterns of passenger travel are partly a consequence of growing wealth. As GDP per capita increases, people tend to migrate towards faster, more flexible and more expensive travel modes. With faster modes, people also tend to travel further. There is also a strong correlation between GDP growth and increase in freight transport. More economic activity will mean more transport of raw materials, intermediary products and final consumer goods (Krewitt, et al., 2008). In India, motorization is still low but car ownership is increasing fast as GDP increases. Car ownership per capita increased at annual average rate of 25% between 1975 and 1980, at 13% between 1980 and 1990 and at 7.4% between 1990 and 2002. Energy consumption in the transport sector currently represents a small share of the total energy consumption in India (15%). However, motorized vehicle ownership is increasing very rapidly as well as the need to transport goods across the country. (Can, Letschert, McNeil, Zhou, & Sathaye, 2009).

### 2.1.3 Industry Demand

The worldwide average share of industry in total final energy demand today is 30%, with the highest share of 47% in China, and the lowest share of 19% in Africa (EIA, 2009). The industry sectors with the highest energy demand are the chemical and petrochemical industry, the iron and steel industry, and the processing of non-metallic minerals. These three industry sectors contribute to nearly 60% of worldwide industrial final energy consumption (Krewitt, et al., 2008). Industrial energy demand varies across regions and countries of the world, based on the level and mix of economic activity and technological development, among other factors. Industrial energy use also includes natural gas and petroleum products used as feed stocks to produce non-energy products, such as plastics. In aggregate, the industrial sector uses more energy than any other end-use sector, consuming about one-half of the world's total delivered energy (EIA, 2009). As seen in 2-10, the OECD industrial energy demand is expected to fall as a result of the relatively mature economies, ongoing efficiency gains and a decline in heavy manufacturing as a percentage of OECD economies (ExxonMobil, 2009). This is consistent with the robust economic growth and continued industrialization of the developing world. OECD economies generally have more energy-efficient industrial operations and a mix of industrial output that is more heavily weighted toward non-energy-intensive

**2-10 Global Industrial Energy Demand by Sector and Area**



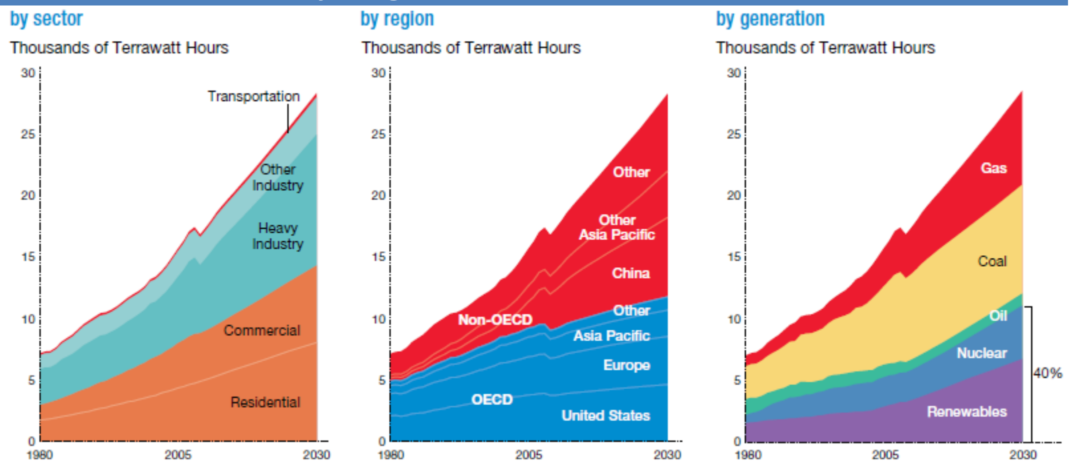

**(ExxonMobil, 2009)**

sectors than in the non-OECD countries. As a result, the ratio of industrial sector energy consumption to total GDP tends to be higher in the non-OECD economies than in the OECD economies. On average, industrial sector energy intensity in the non-OECD countries is double that of the OECD countries (EIA, 2009).

### 2.1.4 Power Generation

Power generation is not only the largest energy-demand sector, but also the fastest-growing as the demand for electricity is growing quickly. Electricity consumption, as seen in residential, commercial and industrial demand factors is strongly correlated to improving living standards Power generation energy consumption is rising at an average of approximately 1.7 percent a year and accounts for about 40 percent of all energy demand, up from 36 percent in 2005

**2-11 Growth in Electricity Usage**




**(ExxonMobil, 2009)**

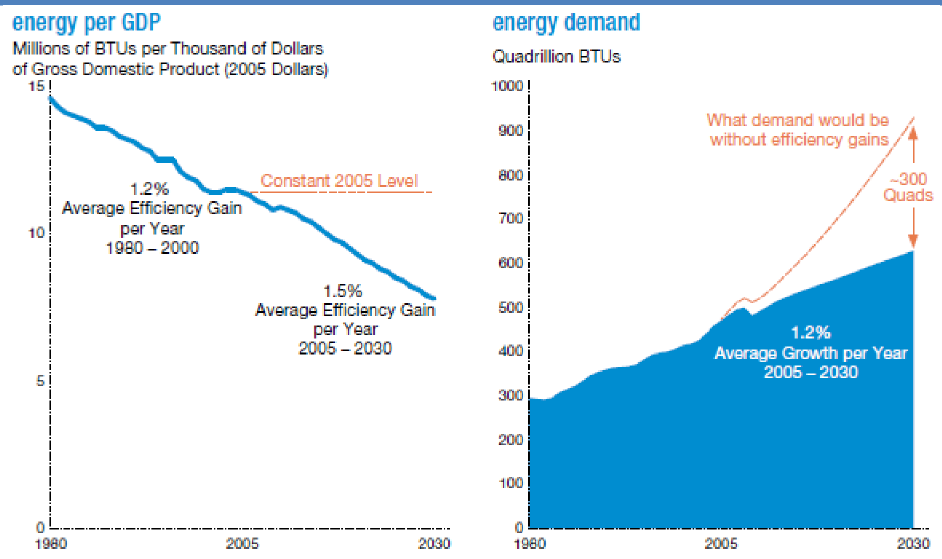
and 26 percent in 1980 (ExxonMobil, 2009). 2-11 shows the massive growth in electricity demand that has occurred and is expected to continue going forwards. Global electricity demand doubled from 1980 to 2005. Going forwards growth is expected to be highest in non-OECD countries as living standards in these countries increase.

## 2.2 Energy Efficiency

Energy efficiency improvement has been important to maintain the global energy balance over the past 30 years. Without energy efficiency improvements, the OECD nations would have used approximately 49% more energy than was actually consumed as of 1998 as shown in 2-12 (Geller, Philip, Rosenfeld, Satoshi,

& Fridtjof, 2006). The energy efficiency improvements achieved across the OECD countries show that well-designed policies can result in substantial energy savings. In the United States nine specific policies and programs reduced primary energy use in 2002 by approximately 11%. (Geller, Philip, Rosenfeld, Satoshi, & Fridtjof, 2006) . Figure 2-12 shows how energy use per GDP has seen efficiency gains averaging 1,2% from 1980 to 2000 globally. This has been achieved as major OECD countries have significantly reduced the need for energy to fuel economic growth over the last three decades. Today major OECD economies use a third less primary energy to generate a unit of GDP than in 1973. These efficiency gains started as a direct result of the two oil price shocks. Between 1973 and 1983, the fall in primary energy intensity averaged 2.2%/year. After 1983 and until 1990, TPES/GDP declined at a more modest average rate of 1.3%/year (Geller, Philip, Rosenfeld, Satoshi, & Fridtjof, 2006) It remains to be seen what will be the longer lasting efffect of the 2007/2008 price shock.

**2-12 Global Energy Efficiency Development**




**(ExxonMobil, 2009)**

While energy intensity grew in many developing countries, in China, between 1980 and 2000, primary energy demand rose by a factor of two, while GDP increased six-fold. As a result, energy intensity improved by nearly 6% per year during this period (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). However, between 2002 and 2004, energy demand grew much faster relative to GDP, causing energy intensity to rise. This reversal was driven mainly by surging electricity demand (met largely by increased coal use) and by the manufacture of metals, building materials and chemicals for infrastructure and for consumer goods for domestic and export markets. Between 2000 and 2005, primary energy demand unexpectedly jumped by 55% while GDP increased by 57%. In the three years to 2005 alone, energy demand rose by 44%, almost entirely as the result of coal-based electricity generation. That increase, 530 million tonnes of oil equivalent, is equal to total primary energy use of Japan in 2005. Since 2005, intensity has once again begun to fall, in part due to strong government action to rein in energy-demand growth (Can, Letschert, McNeil, Zhou, & Sathaye, 2009).

While the global energy usage has become more efficient over the last 30 years or more, energy efficiency has not resulted in a reduction in primary energy consumption. For example, the heat loss of the UK domestic stock has decreased by 30% and the efficiency of heating systems has improved by 30%, but primary energy use has increased by 30% (Barrett, Lowea, Oreszczyna, & Steadmana, 2008). This is due to the fact that offsets in intensity generally results in increased demand for energy services. For example, technology that could have been used to increase vehicle miles per gallon in light duty vehicles has been used to increase vehicle horsepower and weight. Likewise, improvements in the efficiency of appliances and buildings have been offset by increased numbers of appliances and building sizes (National Petroleum Council: Raymond, 2007). So, while more efficient technologies reduce the energy demanded by the device, it also changes the total expenditure on a service. For example, a low-energy refrigerator will reduce the total cost of cooling food and low energy light bulbs reduce the cost of providing lighting. If the total cost of a service is decreased, the money saved is likely to be directed elsewhere to create a re-spending effect. If the money saved is spent on a commodity with greater energy intensity, there will not be growth with less energy. This phenomenon is referred to as the take-back, or the Khazzoom–Brookes effect (Barrett, Lowea, Oreszczyna, & Steadmana, 2008) by economists. The effect is such that energy efficiency improvements may actually have a negative effect on the total primary energy demand, explaining the 30% increase in energy demand seen in the UK while they have seen large efficiency improvements. However, at the same time, if the efficiencies had not been implemented, it is uncertain if the S-curve seen in 2-4 would have had the shape or if growth would have continued further before levelling off due to income restraints.

As seen under the demand factors, power generation one of the largest energy demand factor. It is also an area that generates a lot of waste as electricity production requires on average three times its final energy content consumption (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). Final energy consumption represents the direct amount of energy consumed by end users while primary energy consumption includes final consumption plus the energy that was necessary to produce and deliver electricity. In the case of India, the factor that converts final electricity consumption to primary energy is relatively high and was equal to 4.2 in 2005 (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). As a result, consuming one unit of energy from electricity is equal to consuming more than four units of energy at the source of generation. Two reasons explain this large primary energy conversion factor: first electricity distribution and transmission losses are substantial, representing 31% of electricity production in 2004 and second electricity is generated for a large part (82%) with the use of fuel combustion with low efficiency (26% for coal, 28% for oil and 41% for gas). Indian transmission and distribution losses are among the highest in the world. (Can, Letschert, McNeil, Zhou, & Sathaye, 2009). Based on this, there exists a huge potential for reducing energy lost before it reaches the consumer, which should result in increased energy efficiency without the risk of the take-back effect, unless generators pass on the savings to consumers. This could potentially be regulated through taxes or other measures by policymakers.

## 3. Policy and Pricing Implications

Energy is essential to the economic activity that sustains and improves the quality of life (National Petroleum Council: Raymond, 2007). As such, growth in the use of energy is essential if billions of people living in the developing world are to see improved living standards and as a result, quality of life. By providing reliable and affordable energy, policy makers will help revitalize economies and enable broad economic gains around the world. As shown in the energy demand section, demand in non-OECD countries, has with the exception of China been increasing more than linearly with respect to income. This shows that countries face increasing energy intensity during their development path as they climb the energy ladder, as shown in graph 2-3 The Energy Ladder and 2-4 The Energy Ladder S-Curve. How energy intensity will grow is affected by a number of factors such as geographical location, size, and climatic exposure. In addition, factors such as industrial structure, efficiency and mass mobility solutions are significant and are the results of explicit economic and policy choices made by countries (Benthem & Romani, 2009). These are important factors to take into account when building an energy policy. Further, it has been shown that energy demand is more responsive to end-use price rather than international oil price changes. This is because taxes, subsidies and losses from transportation and conversion vary widely across countries and has a large impact on the end user price (Benthem & Romani, 2009). In addition, the magnitude of demand responses to price changes is substantial in the developing world, varying more than linearly with price levels. This indicates that the steeper the end-use price increase, the stronger the marginal reduction in energy demand which indicates a higher degree vulnerability of developing countries to increasing energy prices (Benthem & Romani, 2009).

3-1 Correlation Between International Oil Price Index and Domestic End-Use Energy Price Index

| Non- OECD | | | | | |
|---|---|---|---|---|---|
| Indonesia | -14 % | China | 19 % | Malaysia | 58 % |
| Mexico | -7 % | Peru | 20 % | Chile | 61 % |
| India | -1 % | Algeria | 33 % | Thailand | 68 % |
| Romania | 6 % | Pakistan | 36 % | Sri Lanka | 76 % |
| Brazil | 10 % | Colombia | 41 % | South Korea | 77 % |
| Argentina | 16 % | Venezuela | 46 % | Philippines | 83 % |

| OECD | |
|---|---|
| US | 93 % |
| Western Europe | 60% - 90% |

**(Benthem & Romani, 2009)**

3-1 shows that the correlation between end user price and the international oil price is highly variable across both the developed and developing worlds. It is close to 1 in the US where increases in oil price are likely to quickly flow through to the gas pump. As a result of the difference in correlation between the international oil price and the end user energy price the relationship between energy demand, growth and prices in developing countries can be fundamentally different from that in OECD countries (Benthem & Romani, 2009). It is also important to note that it has been shown that demand is far more responsive to income than to price (National Petroleum Council: Raymond, 2007). This is important because it shows that the effects on developing economies that depend on growing energy usage to feed economic growth are more negatively affected by high prices than the developed world. It also shows that the energy prices in the developed world have to be significantly higher than in the developing world for demand to change, which may have an impact on economic growth. Such differences are important for energy policy makers to take into account when trying to set up policies that will support a safe, reliable and affordable energy supply even as populations and economies grow pushing demand higher, to support improved living standards quality of life for both the developed and developing worlds

## 3.1 Climate Change is Real

Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global energy supply that is sustainable versus a climate change scenario (Krewitt, et al., 2008). Energy demand growth is unavoidable as economies growth and living standards improves in developing nations. However, if the increased demand is met through increased use of fossil fuels, in a context where the global climate is changing as a result of carbon emission, it is likely that the same developing nations will experience negative consequences such as drought and extreme weather as a result of climate change. To avoid such a scenario, energy demand growth has to be met through the use of cleaner technologies seen in existing and new technical solutions, more efficient use of energy and behavioural change in large parts of the world.

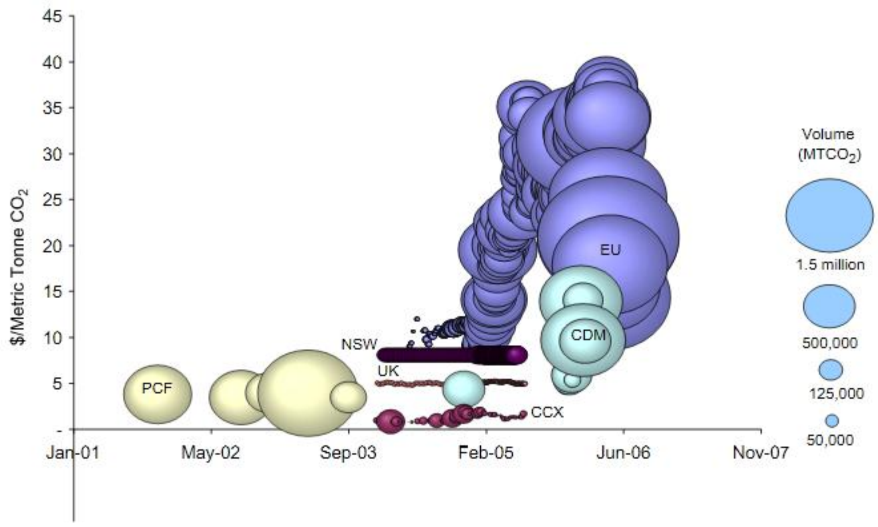
Efficient and renewable supply, distribution and end-use technologies have multiplicative effects, but constraining demand growth is crucial to the rate and extent of reducing emissions (Barrett, Lowea, Oreszczyna, & Steadmana, 2008). Clearly, the developed world will have to reduce its emissions to provide room for emissions from developing nations or will have to support a massive expiation of renewable energy generation in the developing world. To limit a global average temperature increase to around 2°C (estimated to be the level that will prevent dangerous interference with the climate system), global CO2 emissions will have to be stabilized around 10 Gt/a in 2050 (Krewitt, Simona, Graus, Teske, Zervos, & Schäferd, 2008). To be able to achieve such a goal renewable energy will have to provide as much as half of the world's energy needs by 2050 which would include OECD countries limiting their emissions by as much as 80% (Krewitt, Simona, Graus, Teske, Zervos, & Schäferd, 2008). To be able to meet these incredibly ambitious targets, energy policies need to be put in place to develop a low-carbon economy. Such a policy would need to include energy pricing reform and policies for promoting energy efficiency and renewable energy generation in addition to addressing the issue of carbon leakage. Below is a list of four critical energy policy issues related to achieving a global reduction in carbon emissions and the potential for global warming (Pezzey, Jotzo, & Quiggin, 2007):

- **Emission pricing:** A globally efficient (i.e. cost-effective) policy requires emissions cuts at a similar marginal cost in all countries, and on all sources of emissions where control policies are practicable. By emissions pricing it is meant that governments create fairly pervasive, fairly uniform price incentive to reduce emissions. Governments do this either by setting an overall emissions cap and allowing emissions permit trading within it (cap and trade); or by taxing emissions or with some hybrid combination of trading and taxation (Pezzey, Jotzo, & Quiggin, 2007).
- **Technology policy:** Government supports that include: subsidies for private R&D and direct spending by government R&D agencies (Pezzey, Jotzo, & Quiggin, 2007).

- **Removal of barriers to behavioural change:** Demand-side energy efficiency improvements form a large share of low-cost options for carbon abatement; but consumers and producers often fail to take up options already highly cost-effective at current energy prices. There is therefore a need, even with emissions pricing, for well-designed and targeted regulatory measures to gradually eliminate these barriers. Such measures include minimum standards for buildings and appliances; labelling, advertising and providing information and subsidising selected energy efficiency investments (Pezzey, Jotzo, & Quiggin, 2007).
- **Minimise carbon leakage:** Carbon leakage is higher emissions and output from foreign competitors not subject to emission pricing, which thus causes domestic economic pain in those sectors, for little global environmental gain. Currently border adjustments (taxes on imports from, and rebates for exports to competing, uncontrolled countries) are well-established and efficient ways of preventing leakages for other commodities (Pezzey, Jotzo, & Quiggin, 2007).

Market pricing of emissions is still in its infancy, however as seen in 3-2, several markets have been established although with limited effect on emissions so far.

3-2 Evolution of Size and Price in Various Carbon Markets



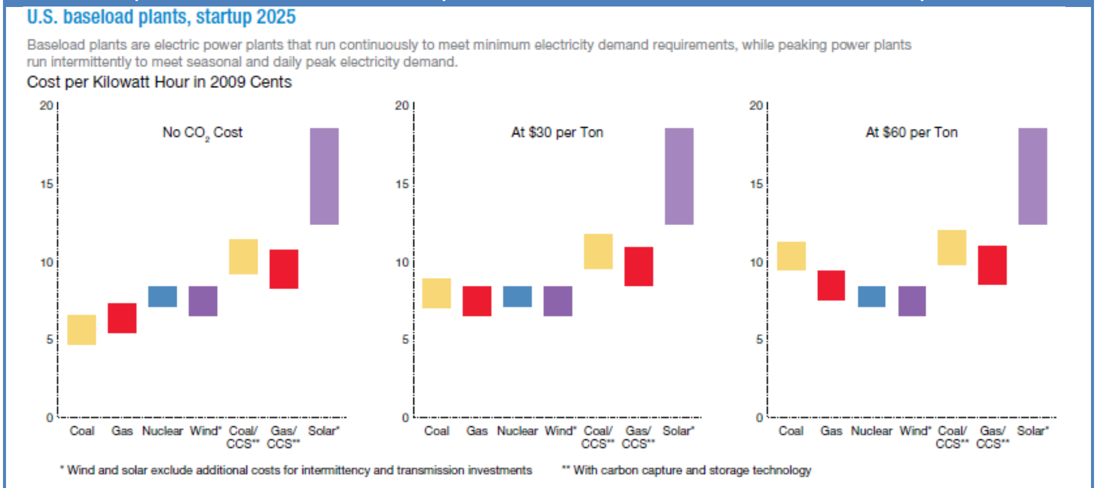

(Zerriffi & Wilson, 2010)

Research into EU's carbon trading scheme has shown that although there were many problems in the first phase, emission cuts were achieved in a cost-effective way, without losing competitiveness. The cost of carbon is also now a firmly established factor in European power market's investment decisions (Chestney, 2010). Two factors may limit the efficacy of market mechanisms as the primary instruments for stabilizing climate. First, carbon taxes high enough, or carbon emission permits scarce enough, to substantially reduce emissions are unlikely to be adopted as it would require substantial political courage. Second, there is doubt about the capacity of carbon taxes or emission permits to induce the necessary technological change (Green, Baksi, & Dilmaghania, 2007). Therefore, a combination of stable and predictable programs will be necessary to best promote growth of technology and restrictions on carbon emissions.

Clearly the pain of carbon abatement cannot be born equally between the developing and developed worlds. However, the cost of increased quality of life for a massive amount of people is not necessarily expensive either in monetary terms or carbon emissions. The IEA estimated that providing another 1.3 billion people with access to LPG by 2015 would result in less than 1% change in global oil consumption. Another estimate shows that eliminating the electricity access problem (i.e., providing electricity to all 1.5 billion people without access at the moment) would result in an increase of CO2 emission of just 0.15 GtC/year ( 2%) (Zerriffi & Wilson, 2010). This indicates that solving the most basic rural energy poverty problems do not significantly increase greenhouse gas emissions. In fact, there is some evidence that the incomplete combustion of biomass in cook stoves may be a significant source of black carbon, carbon monoxide and other products of incomplete combustion that, in fact, have significant climate change implications. If that is the case, then switching from biomass to fossil fuels may in fact reduce net GHG impacts rather than increasing them (Zerriffi & Wilson, 2010).

Although CO2 pricing has many issues, absent any policies that impose a cost on CO2 emissions, it is likely that coal and natural gas are the lowest-cost options for future, as seen 3-3 showing the cost per KW/H under various assumptions. At $30 per ton of CO2, natural gas would become the most economic alternative for new-build power plants. At $60 per ton, natural gas is still competitive, but then also nuclear and wind become competitive (ExxonMobil, 2009). To be able to stabilize climate change technology will have to play an important role, it is therefore important with research and development and eventual deployment of new, scalable carbon emission-free energies (Hoffert et al., 2002; Green, 2000).

3-3 Cost per KW/h, US baseload plants under various CO2 cost assumptions




(ExxonMobil, 2009)

Behavioural change can have as large an impact on emissions as technological change but can be more difficult to implement socially and politically, in particular where consumer choice and behaviour is at hand. Buying smaller, more fuel-efficient cars can reduce fuel consumption directly by 50% or more. Reducing internal temperatures in buildings can save in the order of 10% of space heating, more in highly insulated dwellings. Replacing airline flights with videoconferencing can reduce energy demand for travelling. However, it remains to be seen if shifting behavior can play a larger role in energy efficiency efforts in the coming decades (Geller, Philip, Rosenfeld, Satoshi, & Fridtjof, 2006).

For renewables to become a major factor in the electricity production, policymakers will have to solve several issues in relation to the main renewables available today. Because solar and wind energy are intermittent as well as dilute, only a small proportion of these energies, when fully developed, can be supplied directly to the electric grid. This may to some extent be mitigated by the development of smart grids, which may reduce the intermittency, diluteness and distance problems, but will not eliminate them (Green, Baksi, & Dilmaghania, 2007). Any further contribution to electricity supply by the intermittents must be backed up by stored solar and wind energy and/or by operable and highly flexible operating base load energy supply such as pumped or dammed hydro. Very large amounts of storage (whether in the form of hydrogen, compressed air energy (CAES), batteries, flywheels or pumped hydro) would be required to back up an electricity system that relies heavily on solar and wind energy.

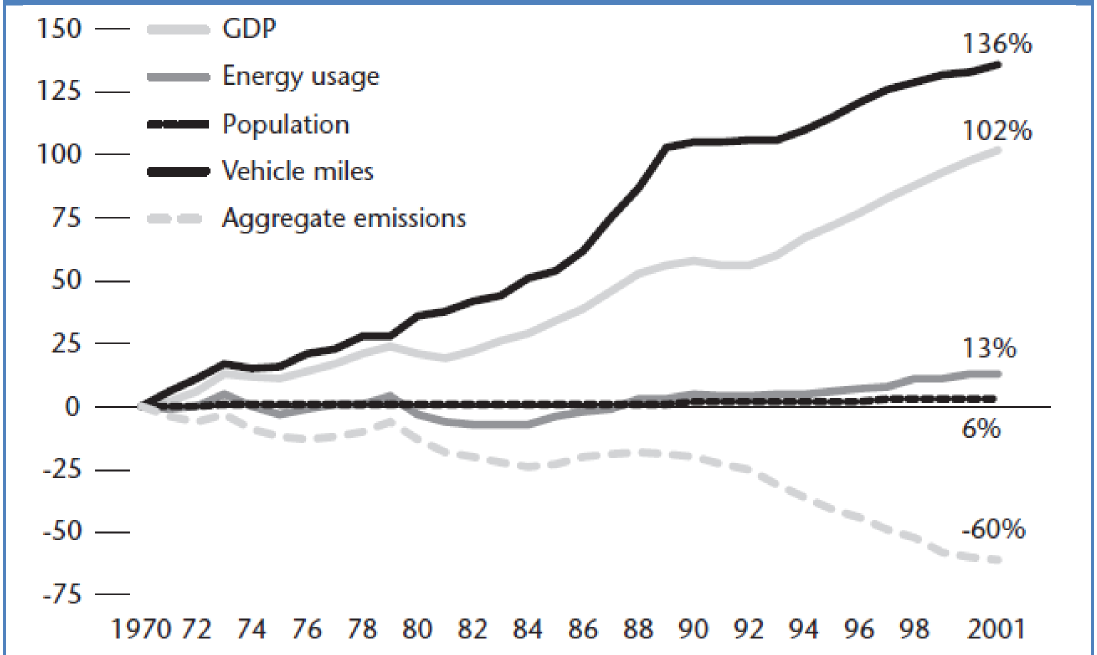
## 3.2 Status Quo – No Man Made Global Warming

Historically, the carbon energy economy has been a great success for improving economic growth and raising global living standards. It has also become less polluting and more abundant, affordable and reliable, particularly in the second half of the last century (Bradley; 2003). This record contradicts the energy Malthusians who have long predicted increasing scarcity, physical shortages, worsening pollution and general crises from increasing dependence upon carbon energies (Bradley; 2003). One of the major challenge policymakers has been to provide energy sustainability and eradicate energy poverty. The World Energy Council and International Energy Agency estimate that approximately 2 million people die prematurely as a result of a lack of access to electricity, relying on wood and dung for home cooking and heating. These people suffer from acute smoke inhalation, subsistence productivity and unsanitary living conditions. This regional energy poverty amid global energy plenty a major challenge for policymakers amid the climate change hype.

Poverty magnifies the effects of extreme weather, earth quakes and other negative events (Bradley; 2003). Therefore poverty eradication should be a major policy imperative. Any climate-change policy reducing energy availability or affordability for populations that are industrialising will have a negative impact in this respect and is likely to create negative net benefit. To the extent that policies are not supporting growth in these countries, climate-change policy can be promoting poverty sustainability rather than energy sustainability (Bradley; 2003). For developed countries where poverty is not acute, a health is wealth standard should guide public policy (Bradley; 2003). In this setting, it would make sense for policymakers to utilize the least expensive fuel sources instead of putting small and hypothetical risks ahead of better understood costs and benefits (Heartland Institute; 2007). It is known that coal, natural gas, and nuclear power can be used to generate electricity safely and cleanly. Without carbon based energy supplies, there is a risk of supply interruptions and rising costs, which in turn will reduce economic growth and job creation (Heartland Institute; 2007).

It should be noted that even though the use of carbon based energies has been increasing fast across the globe, air, land and water pollution associated with carbon energies is declining in the UK, the USA and much of the rest of the world (Bradley; 2003). 3-4 shows how a doubling of real gross domestic product (GDP) since 1970 has been accompanied by a an 83 percent reduction in sulphur dioxide emissions, 83 percent reduction in nitrogen oxides, 33 percent reduction in particulate matter, 67 percent reduction in carbon monoxide (Bradley; 2003). This shows how economic growth simultaneously acts to limit air pollution as people become more environmentally conscious when they don't have to worry about where the next meal is going to come from.

**3-4 UK Growth Vs. Aggreagate Air Pollution Emissions % (1970 – 2001)**




(Bradley; 2003).

As shown above, even if the climate change scare in relation to the use of fossil fuels is reduced, there are still a range of arguments for reducing emissions of air pollutants in relation to the burning of fossil fuels. Therefore, it can still be favourable for policymakers to introduce pricing systems that encourage cleaner emissions and higher energy efficiencies.

There would also exist opportunities for expanding no-regrets energy policies. In a status quo scenario, public policy towards the climate-change issue should begin and end with win-win reforms (Bradley; 2003). Such policies could include: Removing subsidies that keep energy prices below market levels, thereby reducing energy demand and eliminating related emissions. Introducing peakpricing when demand is highest in transportation and retail gas and electricity markets to reduce demand and eliminate related emissions. Reducing emissions of the air pollutants, especially particulate matter (PM10), nitrogen oxides (NOx) and carbon monoxide (CO), to improve local air quality and reduce health consequences of emissions. Streamline tax codes to facilitate capital upgrades to more energy efficient equipment (Bradley; 2003).

High-energy use places an enormous burden on long and short-term economic development and poses critical problems for developing countries, in terms of improving living standards, and developed countries in terms of the wasteful use of limited resources. Energy inefficiency becomes a drain on factories, machinery and resources, affecting competitiveness. Hence, it is important to invest in the efficiency of the energy supply systems and reduce losses on the demand side (Reddya & Assenza, 2008).

Several factors limit the scope for large-scale production of energy from renewables like solar, wind, and biomass. In particular, there are two major types of limitations. One is technological in relation to storage and grid, the other is resource based land, water and energy intensity (Green, Baksi, & Dilmaghania, 2007). If these constraints can not be overcome it is unlikely that renewables can supply the CO2 free energy needed if we are to believe the climate change supporters (Green, Baksi, & Dilmaghania, 2007). However, renewables can play an important role in providing energy to rural areas, in particular within developing nations, who can benefit from reduced investments in national electricity grids combined with reduced local pollution effects of traditional power generation technologies (Reddya & Assenza, 2008). Furthermore, as long as there exists no real alternative to energy produced from coal, natural gas and petroleum there will exist tradeoffs between environment and health on one side and wealth on the other side.

## 4. Conclusion

In the absence of catastrophic climate change and the swift onset of fossil fuel shortages, incomes in much of the world will continue to rise and it is likely that the use of fossil fuels will follow suit. However, with improved technologies it is likely that there will also be a reduction of energy and carbon intensities per economic value. The important questions from a public policy perspective are: How much of the warming is natural; how sure are we that it will continue; and would continued warming be beneficial or harmful? (Bast 2008). Policymakers need to weight the costs and benefits of the policies that they are considering to implement to create policies that create net benefits rather than net costs. It is not given that wholesale forced reductions in the emissions of GHG will provide such positive effects as the extent of the effect on the environment is uncertain while the costs to both developing and developed countries can be quite high. Mandatory GHG emission reductions beyond the no regrets policies can produce costs in excess of benefits under fairly realistic assumptions (Bradley; 2003) and should therefore be under particular scrutiny.

It is clear that economic growth is likely to produce positive net benefits in combination with policies to limit energy intensity so that policies supporting such growth, in particular within the developing nations are highly likely to generate positive global environmental effects. Furthermore, it is unclear if the current renewable technologies can actually provide the abundant, affordable and reliable supply of energy needed to power the wanted qualities of life for people around the globe so that policies including preparing for climate change and adaption to it are likely to be of high value in the short to medium term. Policies that are expected to be beneficial in the long term, but with high costs today may be more suspect as "in the long term, we're all dead" (Keynes) so the net benefits are difficult to asses.

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