Global Energy Outlook 2050 – Policy Options

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Abstract

The paper analyzes the historical trends, resource distribution and forecasts the regional total primary energy consumption (TPEC) to 2050. The purpose is to provide a most probable path so that appropriate policies can be made to enhance/slowdown the energy consumption without hampering economic growth[2]. Global TPEC is most likely to reach 763-1259 Quadrillion Btu (QBtu) to 2050 with reference case trending between and stood at 978 QBtu. By 2050 the equation of TPEC is expected to be tilted in favor of developing countries when their share is increased from 47 percent in 2003 to 59 percent. Asia developing region becomes the largest consumer of TPEC; however on per capita basis it remains the lowest after Africa. The forecast gives some guidance to policy makers. Which policy measures should be taken to ensure availability of predicted level of energy resources[3]? How should we mobilize sizeable investment to increase the expected production/capacity/logistic both in the producing and consuming countries? Simultaneously, what strategic measures should be taken: to improve energy efficiency/conservation, development/promotion of renewable sources of energies and check population growth to downward shift the probable TPEC path without compromising economic growth, productivity and quality of life?

Le document analyse l'historique des tendances en matière de distribution des ressources et les projections régionales en ce qui concerne la consommation d'énergie primaire totale (CEPT) a l' horizon 2050. Le but est de proposer le plus probable path afin que des politique appropriées soient arrêtées en vue d'accélérer ou de réduire la consommation d'énergie sans impact négatif sur la croissance économique. La CEPT globale atteindra probablement entres 763 et 1259 Quadrillion de Btu a l'horizon 2050 en ayant comme base de référence une projection autour de 978 QBTU. A l'horizon 2050 les projections de l'équation CEPT devraient être en faveur des pays en dévelopement quand leurs parts de marche passeront de 47% en 2003 a 59%, Les régions Asiatiques en développement deviendront les plus larges consommateurs, et cependant sur une base par habitant elles déumeurent les plus faibles apres le continent Africain. Ces prévisions devraient guider les pouvoirs dans leur prise de décision. Quelles sont les mesures a prendre afin de s'assurer avec precison des disponibilités en ressources énergétiques ? Comment mobilier de gros investissements dans le but d'accroitre la production, les capacités de production et la logistique aussi bien dans les pays producteurs que consommateurs? Simultanément quelles sont les mesures stratégiques qui doivent êtres prises pour améliorer l'efficience énergétique, la conservation, le développement et la promotion des

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[1] The views expressed in this paper are those of the author and do not represent views of his organization.

[2] Most probable path means that there is ninety percent probability that regional/global TPEC is likely to grow and would remain within this range.

[3] For example, if the desire is to reduce TPEC from reference case to low case, then the respective regions must prepare to trade their reference case GDP growth and devise policies to cut their population growth by 20 percent annually.

énergies renouvelables ainsi que le contrôle de la croissance démographique dans le but d’inverser la tendance de la CEPT sans influer negativement sur la croissance économique, la productivité et la qualité de vie.

Introduction

Humanity has employed various sources of energies in pursuit of greater comfort, enhanced productivity, enhanced security of supplies and the satisfaction of wants. Historically, increases in the level of economic activity have strongly correlated with the increased energy usage (Ghouri 2006). A distinguished feature of the Industrial Revolution has been the unprecedented increase in productivity due to increasing usage of various forms of energies. However, during this rapid industrialization process, some countries have managed to attain impressive economic growth, while others have lagged behind. What would be the future role of energy for rapid economic growth and for enhancing its affordability to the resource poor consumers in the developing world? What are the key drivers and constraints for economic growth?

The future global primary energy demand is expected to be driven by increasing requirements of the rising population, the overall rate of economic growth, and the availability and affordability of energy; energy fuel mix and the efficiency of current and future energy technologies used by the fast emerging economies. Technology, population growth and the role of renewable sources of energy will be the key factors in influencing the future energy growth path. For example, technology could act as double sword. While it will facilitate in augmenting the energy supplies and reducing cost, it will also be the key to arrest the acceleration in energy demand - energy efficiency and help in reducing emission/conservation.

Uneven Distribution Pattern

Currently out of about 6.3 billion global population, two billion people have no access to commercial energy while one billion have limited or unreliable access. Sixty-seven percent are living in Africa and developing Asia Pacific but jointly consuming only one-quarter of global primary energy in 2003. About 1.6 billion people, mostly living in Africa and South Asia, have no access to electricity and therefore one can anticipate that the largest increase in world energy demand over the next 25-50 years will come from developing countries, subject to availability and affordability. Much of the expected increase in energy demand will be driven by the sectors such as rural and urban residential consumers and those in the industrial sector and others associated with services and transport. Developing and transition countries over the next 25 years will require investments of around $300 billion a year[4]. Therefore a major challenge is to provide basic commercial energy to those:

- two billion people who are resource-poor and are mostly living in poverty with inadequate sources of earnings.
- one billion people who may have access to energy but which is either unreliable or unaffordable.

The other challenge is to ensure that people who have access to commercial energy will continue to maintain the evolving consumption requirements.

[4] Clean energy and Development towards an investment framework, Development Committee (joint Ministerial Committee of the Boards of Governors of the Bank and the Fund on the Transfer of Real Resources to Developing Countries, International Monetary Fund, DC2006-0002, April 5, 2006.

The objective of this paper is three-fold. Firstly to briefly analyze the current distribution of resources, its production, consumption, per capita energy consumption to comprehend the magnitude of the problem. For the purpose of taking some revolutionary policy decisions, one also needs to know the possible long-term demand outlook. Therefore, the second objective is to try to forecast regional demand for TPEC under alternative scenarios using econometric models. That is the purpose is to find out the most probable TPEC path for each region to 2050 under the given economic and population growth rates. Such exercise would at least identify the possible growth in energy demand in various regions and could serve as a road map for policy makers. What policy reforms, measures should be taken now to ensure the availability of predicted level of energy resources by making adequate investment? Or simultaneously, what appropriate measures are needed to be taken to improve the energy intensity, energy efficiency, energy conservation, and development and promotion of renewable sources of energies? Raising Awareness is also required to sensitize the developing countries on the impact high population will have overtime on the energy resources among other issues.

What social policies should be adopted to slow down the high population growth in developing countries? How should we motivate developing countries to resolve internal disputes amicably and provide attractive environment for foreign investments in the energy sector? How should public-private partnership be encouraged as well as efficient demand management policies be adopted to slow down the primary energy growth without compromising the economic growth, productivity and quality of life. "***The decisions countries make today on energy policies and technology will have long-term consequences for the sustainability of growth and for the health of our environment***" - Paul Wolfowitz[5]. Finally, what measures and policies should be under taken by the developing and developed countries - complemented by multinational energy companies to ensure adequate investment to increase the indigenous energy supplies particularly in energy deficient countries? Moreover, ensure transfer of technology including renewable energy; create employment opportunities for locals so as to uplift the quality of life in an effort to reduce wide-regional disparity.

Distribution and Consumption - Historical Analysis

The task is formidable especially if one analyzes the distribution of natural resources that are mainly concentrated in few countries. For example, five countries are holding major chunk of global reserves – oil 59.48% (Saudi Arabia, Iran, Iraq, Kuwait and UAE), natural gas 63.55% (Russia, Iran, Qatar, Saudi Arabia and UAE) and coal 70.92% (USA, Russia, China, India and Ukraine). The remaining resources are being shared by several countries and some of them are totally dependant on other countries for meeting their energy requirements. Against the distribution of resources, 67 percent of the global populations of 6,319 million in 2003 were living in Africa and Asia developing countries and most of them are living below subsistence level (Figure-1). It should be noted that it is not only the skewed distribution of natural resources and population, but also a major portion of various sources of energy that is produced and consumed by five countries in the world. Eighteen countries are the major players either as holders of natural resources, as producers or consumers or all three areas. These eighteen countries are Saudi Arabia, Iran, Iraq, Kuwait, UAE,

[5] President World Bank, for reference see note 4.

Russia, Qatar, USA, China, India, Ukraine, Mexico, Canada, UK, Australia, South Africa, Japan and Germany. Table-1 demonstrates a matrix that shows how these resources are distributed, produced and consumed by top countries in respective sources of energy. United States is the largest single producer and consumer of oil, natural gas and coal. Three countries USA, China and India are the major holders of coal reserves as well as producers and consumers. While for natural gas Iran, Russia, Canada, USA and UK are the major producer and consumer. Some other countries represent either among the top five as reserve holders, producers or consumers.

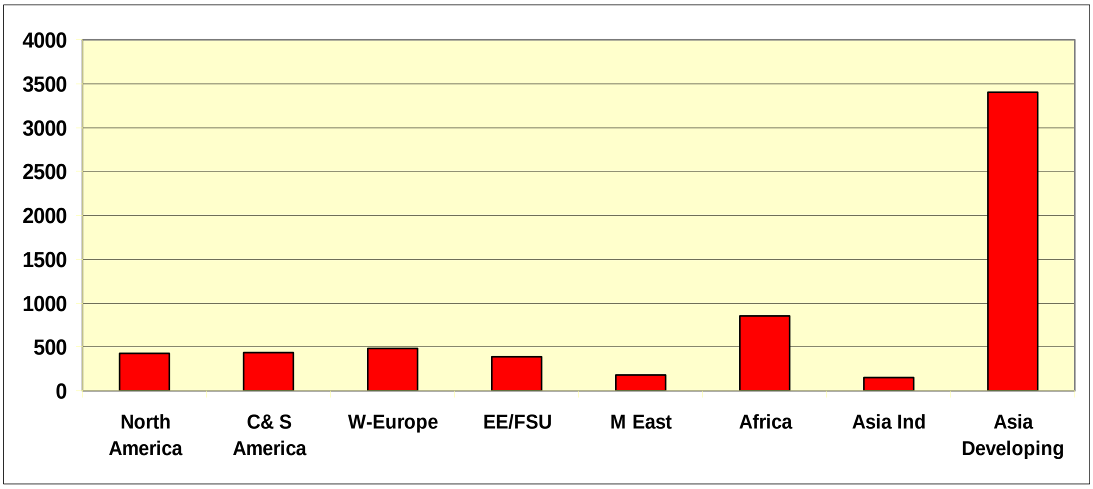

Figure-1: Regional population end 2003 (million).

During 1980 to 2003 global total primary energy consumption (TPEC) increased at an annualized rate of 1.72 percent from 283.412 QBtu in 1980 to 421.513 in 2003 (Figure-2). At the end of 2003, out of 421.513 QBtu, four regions were consuming bulk of global energy resources while three regions (Central & South America, Africa and Middle East) accounted for just 13 percent (Figure-3). With the exception of EE/FSU the rest of the regions recorded an increase in TPEC though incremental increase varied noticeably.

Table-1: Matrix – Summary of distribution, consumption and production of resources by five countries.

Countries	Oil	Natural Gas	Coal
Saudi Arabia	**X, Y**	**X**	
Iran	**X, Y**	**X, Y, Z**	
Iraq	**X**		
Kuwait	**X**		
UAE	**X**	**X**	
Russia	**Y, Z**	**X, Y, Z**	**X, Z**
Qatar		**X**	
USA	**Y, Z**	**Y, Z**	**X, Y, Z**
China	**Z**		**X, Y, Z**
India			**X, Y, Z**
Ukraine			**X**
Mexico	**Y**		
Canada		**Y, Z**	
UK		**Y, Z**	
Australia			**Y**
South Africa			**Y**
Japan	**Z**		**Z**
Germany	**Z**		

Key: X = Top five Countries Reserves Holders, Y = Top five Producing Countries, Z = Top five consuming Countries

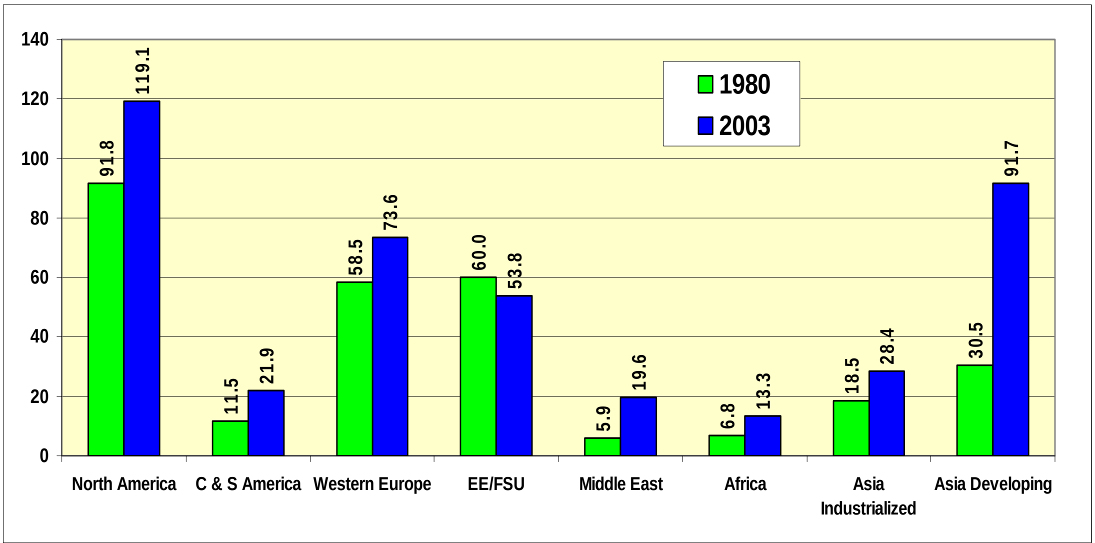

Figure-2: World TPEC – a comparison (Quadrillion Btu)

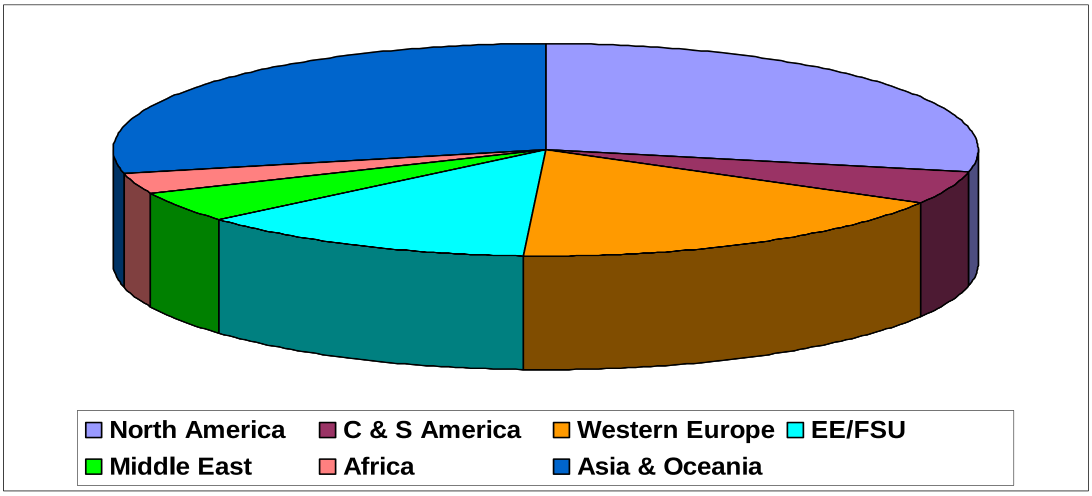

Figure-3: World TPEC (Quadrillion Btu) – 2003

Figure-4 illustrates the snapshot of per capita TPEC pattern at the end of 1980 and 2003, which clearly demonstrates significant variance between the rich and poor. For example, per capita in Africa in the year 2003 stood at 15.7 million Btu[6] as compared to 279.7 million Btu for North America or African were consuming just equivalent to 5.6 percent as that of North American! During the last twenty odd years per capita TPEC declined in North America and EE/FSU while it increased in the other regions with the exception of Africa which almost remained stagnant. The major contributory factor for decline in per capita energy consumption in North America is associated to 37.25 percent improvement in energy intensity while EE/FSU due to disintegration of FSU. Table-2 illustrates the matrix of countries that recorded a reduction in energy intensity during 2003 as compared to 1980. Energy intensity is a ratio of TPEC to real GDP and is generally used to measure the energy efficiency. That is, how much energy a country uses to produce a dollar worth of output. The major contributory factor of reduction in energy intensity is linked with technology, higher energy prices and better management.

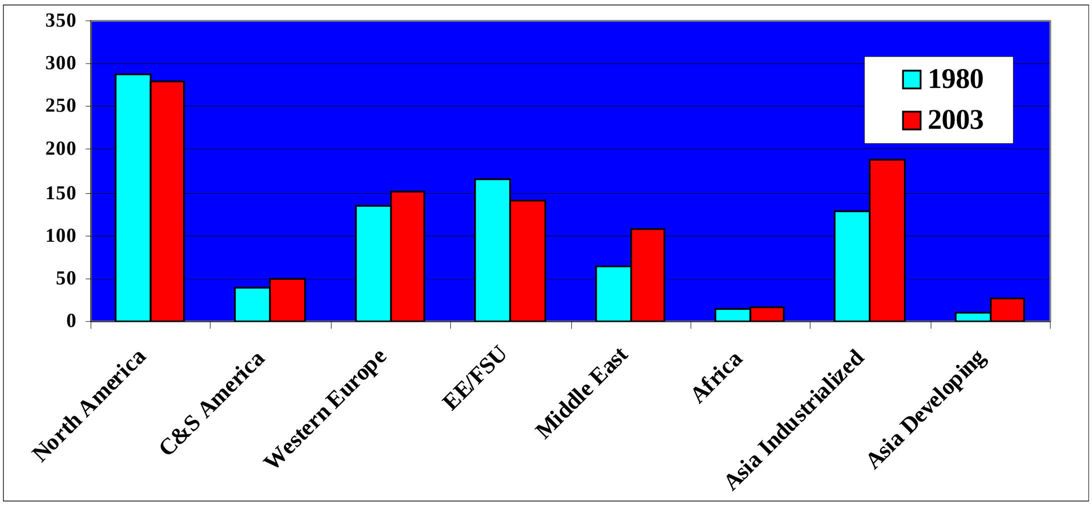

Figure-4: Regional per capita TPEC – 1980/2003 (Million Btu)

[6] British Thermal Unit (Btu), which is the amount of energy necessary to raise the temperature of one pound of water by one degree of Fahrenheit.

Table-2: Matrix of countries recorded reduction in Energy Intensity 2003/1980

Canada	**-25.76**	**Finland**	**-28.22**	**United Kingdom**	**-36.45**
United States	**-37.25**	**France**	**-15.41**	**Bahrain**	**-3.89**
Antigua and Barbuda	**-51.38**	**Ireland**	**-41.33**	**Cyprus**	**-12.91**
Bahamas, The	**-41.43**	**Italy**	**-13.26**	**Australia**	**-15.97**
Belize	**-15.27**	**Luxembourg**	**-56.90**	**China**	**-67.46**
Chile	**-7.66**	**Malta**	**-12.51**	**India**	**-5.02**
Colombia	**-15.30**	**Netherlands**	**-26.70**	**Japan**	**-16.39**
Austria	**-17.92**	**Norway**	**-30.06**	**New Zealand**	**-8.57**
Belgium	**-14.72**	**Sweden**	**-37.05**	**Singapore**	**-5.60**
Denmark	**-32.25**	**Switzerland**	**-19.52**	**Taiwan**	**-10.35**

Energy Outlook - 2050

We have noticed that global TPEC increased by about 48 percent during 1980 to 2003. However, the resources, production and consumption is unevenly distributed. Developed countries represented only about 16.8 percent of global population but consumed over 52 percent of total primary energy in 2003 (Figure-5). As development progresses in less developed countries, growth in energy consumption is likely to increase significantly in developing and emerging economies in Asia, Central & South America and the Middle East during the next 45 years. The energy requirements in Africa remain dependent on resolving regional issues, restoration of civil society and investment in the energy sector. The bulk of energy is expected to be consumed in Asia Pacific developing and emerging economies particularly China, India, Pakistan and other fast growing emerging economies. The rate of energy consumption not only depends upon the rate of economic growth, population growth, availability but also greatly rests on access and its affordability. Energy resources are available but mainly due to their costs, the poor countries do not always import/consume the required energy levels. During the last twenty-five years the world has witnessed a number of negative/positive oil price shocks, which in turn affected the prices of other sources of energy. Ignoring the financial and logistic support, how much total primary energy would be needed assuming the lowest per capita TPEC for Africa is 15.7 million Btu in 2003. At this level, world will require additional 31.4 QBtu of energy resources to provide commercial energy for two billion people who do not have access of commercial energy at the moment. This additional required quantity in 2003 was jointly consumed by Africa and the Middle East regions. This figure does not include energy requirement of another one billion people who have limited or unreliable access.

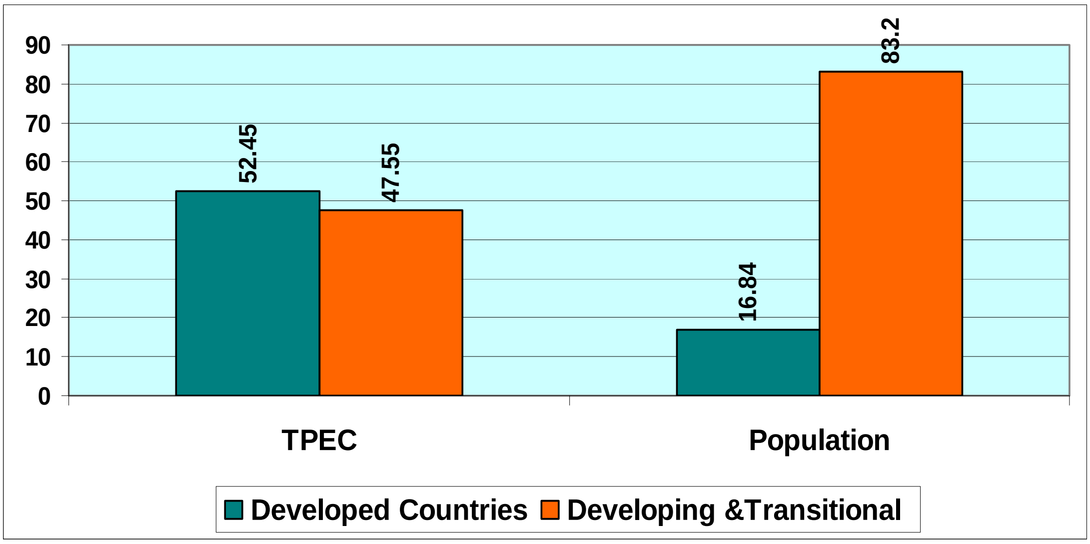

Figure-5: Global distribution of population and TPEC (Percentage share).

What and How to go about?

The first and logical way to forecast regional TPEC is to assume consumption will continue to grow like in the past 25 years to year 2050. To forecast regional TPEC we have used Energy Information Administration (EIA) regional TPEC, population and GDP[7] 1980 to 2003 historical data. The GDP growth rate for reference, low and high growth rate scenario was reported in their International Energy Outlook 2005. For population, EIA reference case growth rate was used. In the absence of any growth rate assumptions for low and high case, it is assumed that regional population is expected to grow by -/+ 20 percent lower/higher than the reference case scenario to account for element of uncertainty. Time trend variable is used in an effort to capture technological advancements over time. Energy prices are important explanatory variables that influence energy demand. However, in the absence of price forecast profile for total primary energy and the inelastic energy demand we have based our regional TPEC forecast on - GDP, population, trend variable and autoregressive-moving average scheme of various orders to find the best fitted model based on historical data 1980/2003.

As we have noticed in previous discussion that there are billions of people who do not have access to commercial energy nor to basic food and drinking water and that they are living in extreme poverty. In contrast, the developed countries are continuously consuming more energy despite significant reduction in energy intensity. As the economies in Asia, Middle East and C&S America set to grow rapidly, the demand for energy in these economies is also likely to increase aggressively. The task of this exercise is to find a most probable path based on historical pattern under alternative scenarios. Once we have the possible range of growth pattern then it would be easier to find out: As to what policy reforms, measures should be taken to ensure availability of predicted level of energy resources by making appropriate policies and adequate investment ; or what appropriate measures need to be taken to improve the energy

[7] GDP in billion of US dollars in 2000 dollars, market exchange rates 1980/2003..

intensity, efficiency, energy conservation, and development and promotion of renewable sources of energy, demand management policies to slow down the primary energy growth without compromising the economic growth, productivity and quality of life.

North America

Figure-6 highlights the probable path of TPEC for North America during 2004/2050. For reference case, North America TPEC requirement is expected to increase at an annualized rate of 1.45 percent – reaching 236 QBtu – an increase of 98 percent compared to 2003. At the end of 2050, the region is expected to consume 236 QBtu of primary energy and its per capita energy consumption will be increased to 369 million Btu – up from 279 million Btu in 2003. For low and high case scenario TPEC is projected to reach at 196 and 280 quadrillion Btu respectively. This is a most probable consumption pattern assuming business as usual. However, with the application of various policy options and innovation in technology, it is quite possible that the probable path could be forced to shift downward. The new-state-of-the-art technology may help in further reduction in cost, increase in energy efficiency both in producing and consuming of commercial and renewable sources of energy. How much downward shift? It is difficult to quantify depending upon the technological advancement, role of renewable sources of energy and combination of various policy options and demand management policies.

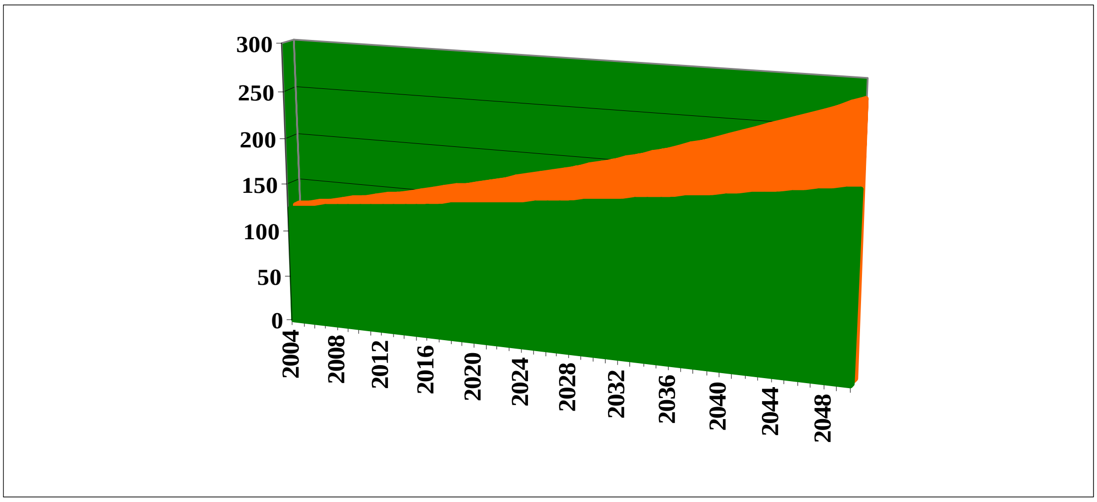

Figure-6: North America Total Primary Energy Consumption - Possible path based on historical relationship (Quadrillion Btu).

Central & South America

Towards the end of 2003, the Central & South America was consuming 21.876 QBtu of TPEC, which represents only 5.2 percent of global TPEC. For reference case the regional GDP during 2004/2050 is projected to grow at an annualized rate of 3.9 percent. It is projected to increase from $1483 billion in 2003 to $8955 billion in

2050. Population on the other hand is projected to increase from 440 million in 2003 to 736 million in 2050. Figure-7 depicts the most probable path for TPEC to 2050. Against the historical annualized growth rate of 2.78 percent during 1980/2003 the regional energy demand is projected to grow at an even stronger rate of 3.35 percent. Towards the end of 2050 the region is projected to consume 105.6 QBtu. The path is bounded by low (76 QBtu) and high case (148 QBtu) scenarios as the reference case is trending in between.

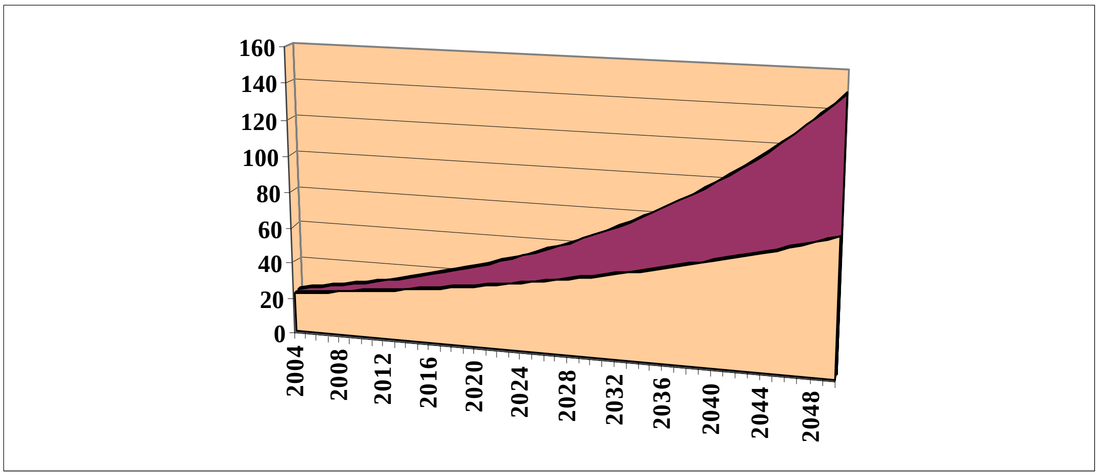

Figure-7: Central & South America Total Primary Energy Consumption – possible path based on historical relationship (Quadrillion Btu).

Western Europe

Unlike developing countries, the mature and well developed European economies are projected to grow at a modest annualized growth rate of 2 percent from $8917 billion in 2003 to $22616 billion under reference case scenario. Despite economic growth rate of 2 percent, TPEC in the presence of heavy energy taxes, other conservative measures and the promotion of renewable sources of energy is projected to increase at a modest annualized rate of 0.87 percent. The regional TPEC is projected to increase from 72.7 QBtu in 2003 to 109 QBtu in 2050 – an increase of about 50 percent (Figure-8). For low and high case scenarios, the model predicts that regional TPEC is expected to increase at an annualized rate of 0.7 and 1.08 percent respectively as compared to 0.99 percent historical average. The probable path shows that if the region follows the historical pattern with the given level of uncertainty, the regional TPEC could fluctuate within the most probable path. By 2050, regional TPEC is projected to be in the range of 100 to 121 QBtu. This trend is further expected to shift downward should the current policies and reforms are successfully implemented - that calls for increasing the role of renewable sources of energy mix and continuous improvement in energy efficiency.

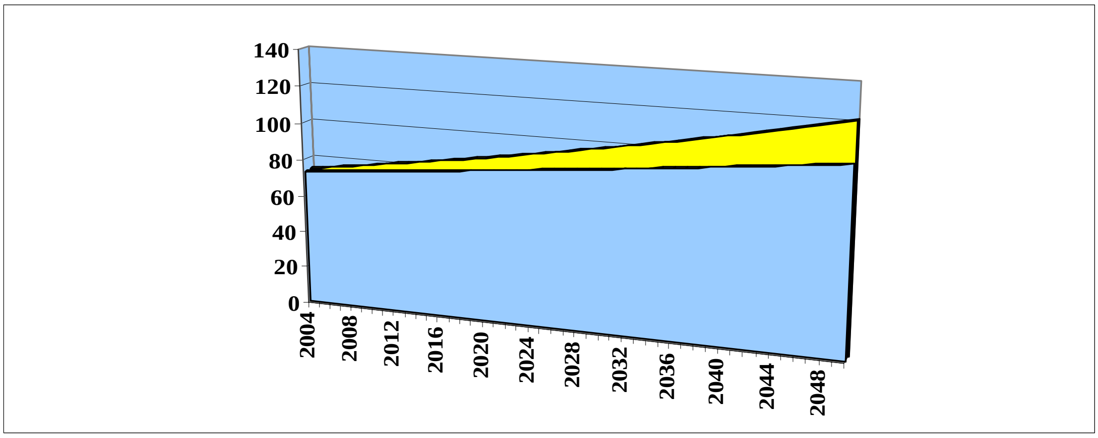

Figure-8: Total Primary Energy Consumption Western Europe – Possible path based on historical relationship (Quadrillion Btu).

EE/FSU

The regional GDP increased from $664 billion in 1992 to $828 billion in 2003. In sharp contrast, the regional TPEC declined from 63 QBtu in 1992 to about 54 QBtu in 2003. The reason mainly associated with the disintegration of Soviet Union and some doubt about the reporting of data as well as some of the countries missing data on TPEC and GDP. For reference case, the model assumes that regional GDP is projected to increase by 4.4 percent and for low and high case; it is projected to grow at an annualized rate of 3.2 and 5.6 percent respectively. These assumptions are the same as that have been used by EIA for their 2002/2050 forecast as reported in International Energy Outlook 2005. The regional population is projected to decline from 384 million in 2003 to 350 million in 2050 for reference case scenario. Based on our econometric model, the regional TPEC is projected to increase at an annualized rate of 1.04 percent – reaching 86 QBtu in 2050 up from 54 in 2003 (Figure-9). For low and reference case scenario, model predicts that the regional TPEC is expected to reach 63 and 105 QBtu in 2050 respectively.

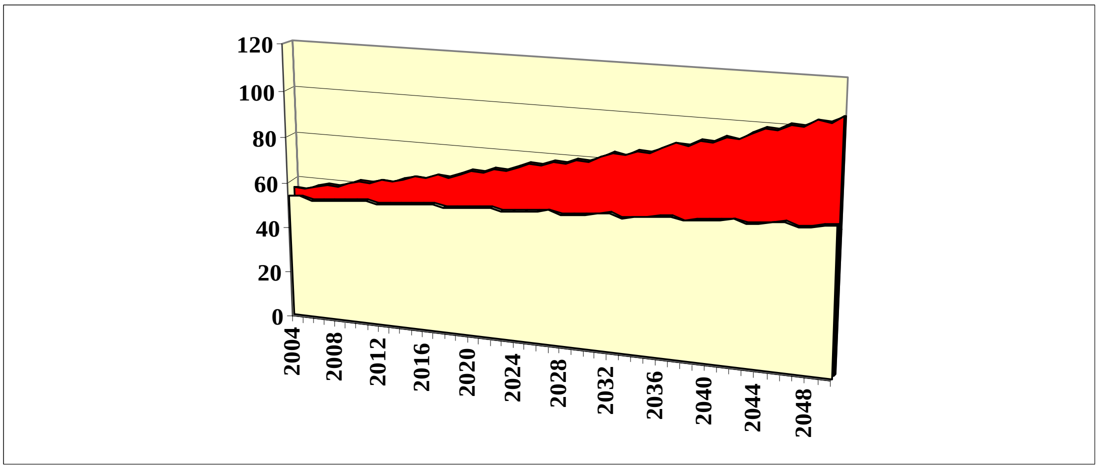

Figure-9: EE/FSU Total Primary Energy Consumption – Possible path based on historical relationship (Quadrillion Btu).

Middle East

The thinly populated regions of the world have immense oil and gas reserves. Despite enormous energy resources, the regional TPEC remain among the lowest in the world. At the end of 2003, the region was consuming 19.6 QBtu of energy, which represents 4.6 percent of total world primary energy consumption. The regional demand for energy is projected to grow rapidly owing to rapid economic growth, increase in population and a number of government initiatives to promote public-private partnership. The model predicts that regional TPEC under reference scenario is projected to increase at an annualized rate of 2.6 percent against 5.2 percent recorded during 1980/2003 (Figure-10). The regional TPEC is projected to increase to 64.8 QBtu towards the end of 2050 – an increase of 229 percent as compared to 19.6 QBtu in 2003. For low and high case scenarios, regional GDP is projected to increase at an annual rate of 3.4 and 5.2 percent respectively. Against these economic growth rates the regional TPEC is projected to reach 50 and 78.7 QBtu for low and high case scenarios by 2050.

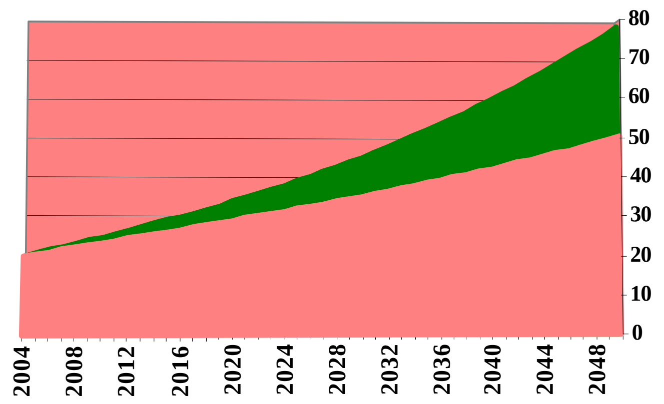

Figure-10: Middle East Total Primary Energy Consumption – Possible path based on historical relationship (Quadrillion Btu).

Africa

Africa's total population of 866 million in 2003 represents 13.5 percent of total global population but the region is lowest energy consumer in the world. At the end of 2003, the region was consuming 13.2 QBtu of TPEC, which represents about 3.1 percent in total global TPEC. The poorest region is not only suffering due to prolonged drought, but the situation is further complicated due to continues violence and civil unrest displacing millions of people – forcing them to take refuge in other neighboring countries. What one could expect in a region where millions of people are starving to death due to the lack of food, drinking water and shelter - what to speak of energy? As a result of these and other factors, the per capita TPEC in the region have been the lowest in the world. At the end of 2003, the regional per capita TPEC stood at 15.7 million Btu – that only equivalent to 5.6 percent of the per capita consumed in North America! Based on the under-lying assumption, our econometric model predicts that the regional TPEC under reference case is expected to grow at an annual rate of 2.7 percent during 2004/2050 – reaching about 40 QBtu in 2050 (Figure-11). For low and high case scenarios TPEC is predicted to respectively reach 31.7 and 49.7 QBtu by 2050

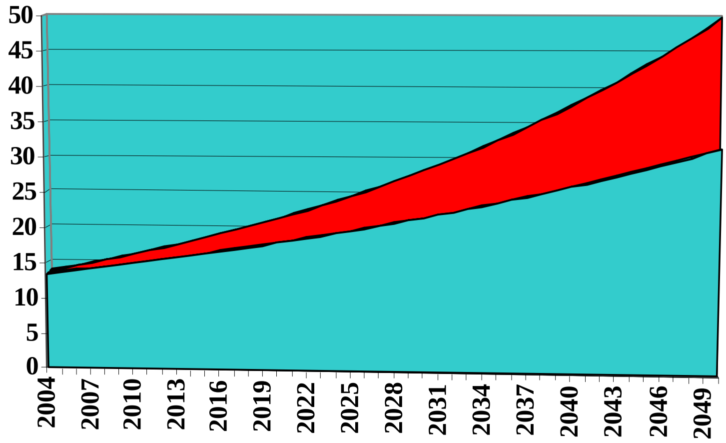

Figure-11: Africa Total Primary Energy Consumption – Possible path based on historical relationship (Quadrillion Btu).

Asia Industrialized

Asia Pacific industrialized countries consist of Australia, Japan and New Zealand. The combined population of these three countries at the end of 2003 stood at 152 million (2.4 percent of total global population) but consumed 6.7 percent of global TPEC. During 1980/2003 their combined GDP increased from $2982 billion in 1980 to $5342 billion in 2003. While during the same period their TPEC increased form 19 to 28.2 QBtu in 2003 – an increase of 47 percent. Incidentally, these three countries also recorded a significant improvement in energy intensity. Based on our GDP and population assumptions, the model predicts that the regional TPEC under reference case scenario is expected to grow at an annual rate of 1.4 percent during 2004/2050 – reaching 54.7 QBtu (Figure-12). Under low and high case scenarios the sub-region TPEC is projected to increase to 44 and 67 QBtu respectively.

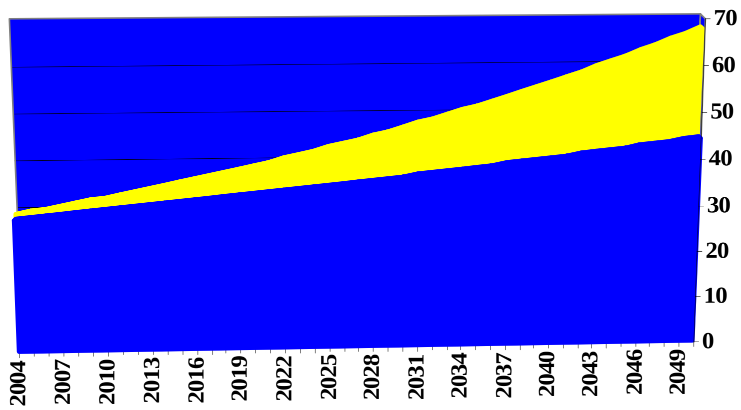

Figure-12: Asia Industrialized Possible TPEC - Possible path based on historical relationship (Quadrillion Btu).

Asia Developing

The developing Asia Pacific consisting of 42 countries (excluding Australia, Japan and New Zealand). More than 53.7 percent of the global population lives in this sub-region. Figure-13 depicts the most probable path for TPEC based on under-lying assumptions and model specifications. The most of the fastest growing economies like China, India, Pakistan etc. are located in this region. For reference case, our model predicts that regional GDP is projected to grow at a robust annual rate of 5.5 percent during 2003/2050. Against this strong economic growth regional TPEC is predicted to grow at an annualized rate of 2.4 percent – reaching 280 QBtu (Figure-13). For low and high case scenarios the model predicted that regional TPEC is expected to reach 199.8 and 407.7 QBtu respectively.

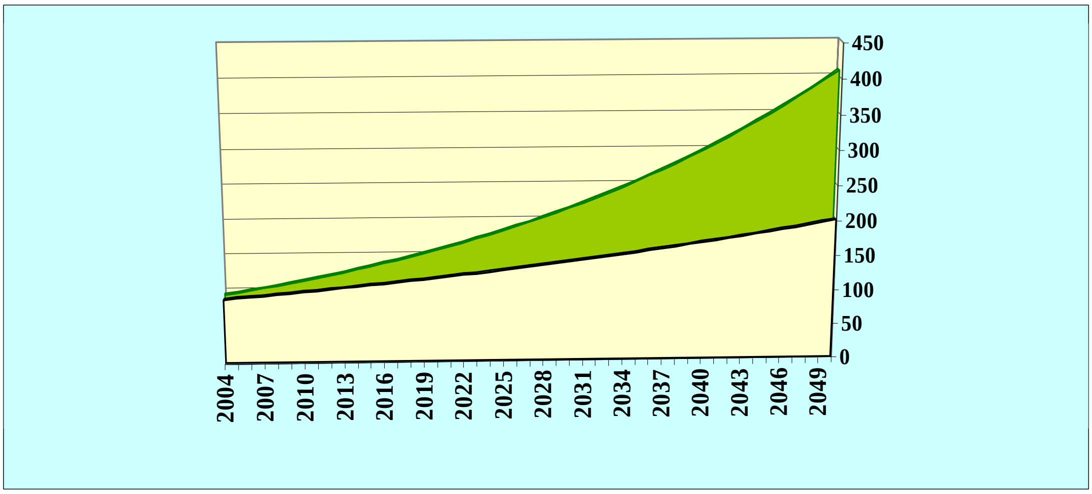

Figure-13: Asia Developing Total Primary Energy Consumption - Possible path based on historical relationship (Quadrillion Btu).

Global TPEC Outlook in 2050

Based on the assumptions used in this study, the global total population under reference case is projected to reach 10 billion – up from 6.3 billion in 2003. With this level of population, the world under reference case scenario is projected to consume 978 Q Btu by 2050 – an increase of 132 percent (Figure-20)[8]. Under low case scenario global population is projected to reach 9.1 billion. Against this population, global TPEC is projected to increase to 763 QBtu by 2050. In sharp contrast, under high case scenario global TPEC is projected to increase aggressively and by 2050, expected to reach 1259 QBtu. The path in Figure-14 depicts the most probable path, however most likely, the global energy demand is projected to fluctuate between low and reference case scenarios i.e., within 763 and 978 QBtu.

[8] The global aggregate population and TPEC is obtained by summing the respective forecast of each region.

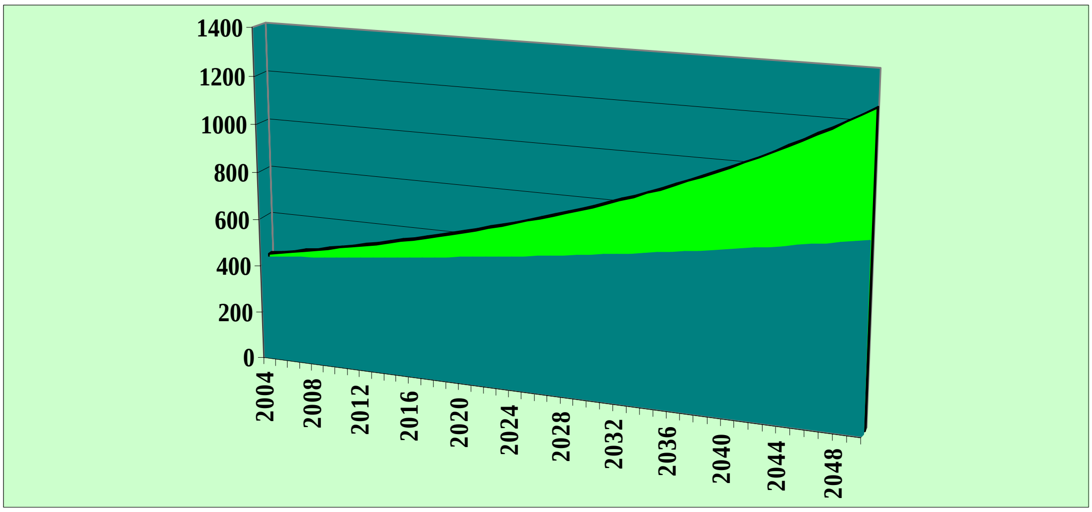

Figure-14: World Total Primary Energy Consumption - Possible path based on historical relationship (Quadrillion Btu).

Comparison of TPEC & Per Capita TPEC

Table-3 tabulated the regional historical and projected annualized growth rate in TPEC under alternative scenarios. Table-4 provides the regional annualized TPEC growth rates of EIA during 2002/2025. Figure-15 highlights the regional comparison of TPEC during 1980, 2003 and 2050. During this period, a significant change is quite visible - Asia Pacific Developing countries are projected to become the largest TPEC consumers surpassing the dominance of North America. However, on a per capita basis, North America remains the dominant TPEC consumer in the world. Although per capita TPEC consumption recorded a significant increase in all the regions during 2003/2050 with the exception of Africa and Asia Pacific developing, which increased modestly (Figure-16)? Despite significant expected increase in TPEC of 205 percent in Asia Pacific developing economies during 2003/2050, the regional per capita increases only by 81 percent mainly due to high population growth rate. In sharp contrast the growth in per capita energy consumption is quite significant in Central and South America and Middle-East. By 2050 the pattern of TPEC is projected to be tilted in favor of developing economies. For example, during 2003, developed countries were consuming 52.4 percent of global TPEC against their population of 16.8 percent. However, by 2050 this equation is projected to change when developing countries are projected to jointly consume 59 percent of TPEC under reference case scenario and the share of developed countries projected to slip to 41 percent (Figure-17). The reason for such increase is mainly due to increase in their global population share to 87.3 percent as compared to about 83 percent in 2003, strong economic growth, and energy is expected to reach most of the population.

Table-3: Annual average growth rate in Total Primary Energy Consumption (%) – history & Forecast

	Historical 2003/1980*	Low 2004/2050	Reference 2004/2050	High 2004/2050
North America	1.13	1.02	1.42	1.79
C&S America	2.78	2.65	3.35	4.07
W-Europe	0.99	0.7	0.87	1.08
EE/FSU	-0.47	2.08	2.39	2.61
M-East	5.24	2.06	2.6	3.01
Africa	2.92	1.87	2.38	2.82
Asia Industrialized	1.87	0.92	1.41	1.85
Asia Developing	4.78	1.69	2.4	3.2

* Based on Energy Information Administration (EIA) data historical growth rates have been calculated.

Table-4: Annual average growth rate in Total Primary Energy Consumption (%) – history & Forecast (EIA 2002/2025)

	Historical 2003/1980	Low 2002/2025	Ref 2002/2025	High 2002/2025
North America	1.13	1.1	1.4	1.7
C&S America	2.78	1.7	2.3	2.8
W-Europe	0.99	0.3	0.5	0.8
EE/FSU	-0.47	0.38	1.04	1.46
M-East	5.24	1.9	2.5	3.1
Africa	2.92	2.2	2.7	3.2
Asia Industrialized	1.87	0.5	0.7	1
Asia Developing	4.78	3	3.5	4.1

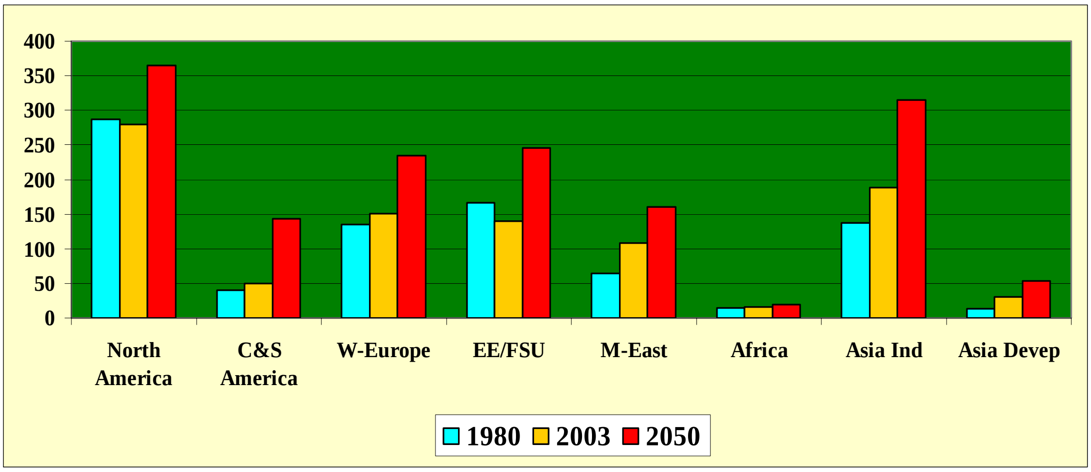

Figure-15: Regional Per capita Total Primary Energy Consumption (TPEC) – history & Forecast.

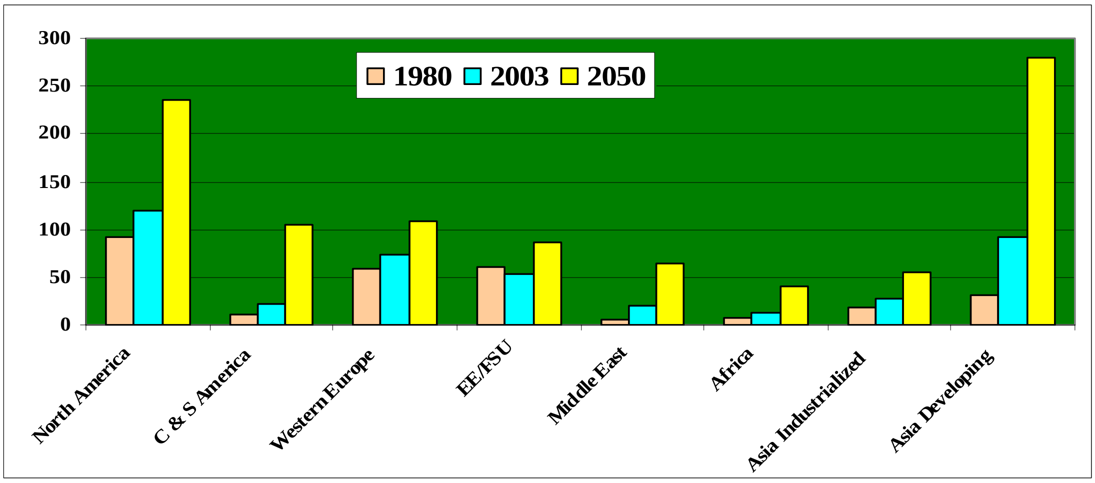

Figure-16: Regional Total Primary Energy Consumption – history & Forecast.

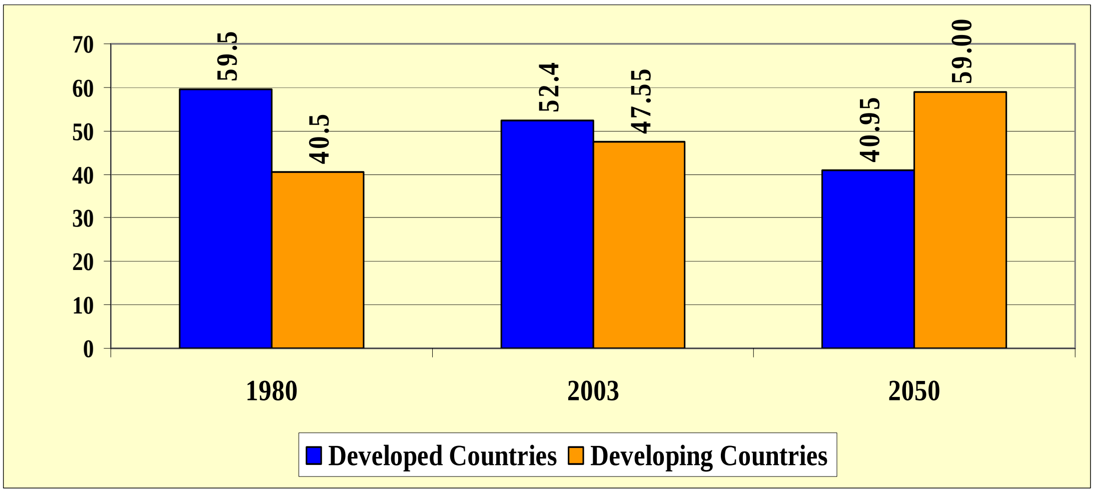

Figure-17: Distribution of Total Primary Energy Consumption history and future.

Challenges - Policy Options

The task of increasing total primary energy supplies to meet the projected level of TPEC is formidable and calls for mobilization of huge capital resources both in upstream, downstream and all spectrums of energy activities. The task is even more complicated as energy resources are located far from the major consuming countries. Therefore, a substantial capital investment is also required to improve, enhance the transport, storage, and other logistic infrastructure in both the producing and consuming countries. The distribution of energy resources to the global population and to enhance their accessibility is a big challenge before the policy makers. At the same time what policies are devised to downward shift the probable TPEC demand path in support of sustainable economic development?

The following table illustrates if the objective is to reduce TPEC from given reference path to low case scenario – what policy options should be taken? The reduction of

TPEC of 215 QBtu is achievable during the projected course of time if each region prepares to trade off their respective economic growth (between Reference/Low case scenarios) and devise policy options that could cut down their reference population growth rates by 20 percent (Table-5). For example, with the reduction of North America GDP from 3.1 to 2.6 percent annualized rate and with 20 percent reduction in population growth compared to reference case, the region could reduce its TPEC by 40 QBtu to 2050. Similarly one can analyze for other regions. Though it is somewhat simple form of analysis, nevertheless at least it sheds some light on the policy options and its implications on TPEC.

Table-5: Policy trade off to shift TPEC path

	Reference TPEC (QBtu)	Low TEPC (QBtu)	High TPEC (QBtu)	Reduction in TPEC QBtu by 2050	Reduction in GDP (%)
North America	**236.37**	**195.58**	**280.37**	**40.80**	**0.5**
C&S America	**105.95**	**76.38**	**148.70**	**29.57**	**0.9**
W-Europe	**109.40**	**100.89**	**120.99**	**8.50**	**0.4**
EE/FSU	**86.38**	**63.56**	**105.57**	**22.83**	**1.2**
M-East	**64.83**	**50.34**	**78.73**	**14.49**	**0.9**
Africa	**40.40**	**31.77**	**49.72**	**8.63**	**0.9**
Asia Industrialized	**54.69**	**44.42**	**67.26**	**10.27**	**0.5**
Asia Developing	**280.03**	**199.85**	**407.69**	**80.18**	**0.9**
Total World	**978.05**	**762.78**	**1259.03**	**215.27**	

Given the unequal distribution of natural resources, a possible option to follow is to promote efforts to reduce regional disparity. Policies that could promote public-private partnership and global integration could be considered. Private investors generally look for stable political system, stable and transparent government policies, peaceful and stable law and order situation, and other fiscal incentive driven policies. Therefore to attract sizable investment in energy related projects, it is the responsibility of poorly endowed governments to provide investment friendly transparent environment. For example, oil and gas exploration itself is highly risky and capital intensive venture. Companies are least interested in investment in countries if they perceive target country is politically unstable, suffers from civil unrest, law and order problem, suffers from unattractive fiscal terms even if otherwise they are geologically attractive ventures. Therefore, as a prerequisite, both the developing countries and multinational oil and energy companies must work in tandem – both must do their part. The government of poorly developed countries must also take appropriate social policies to check their high population growth rates, improve education and health facilities to improve the quality and productivity of labor force.

Promote Renewable Sources of Energies

Much of the increase in energy demand over the next 45 years is expected in residential and industrial sectors and therefore expected to be associated with electricity and transport fuel. Therefore, renewable sources of energy can play a critical role in deciding the future supply of energy mix, rate of growth for TPEC and the rate of economic development. For example, since 2001 biofuel production has doubled and is now set for even stronger growth as the industry is aggressively responding to current higher fuel prices. In 2005, global production of biofuel increased to 670,000 barrels daily – meeting equivalent of about one percent of transport sectors requirements. Although oil still accounts for more than 96 percent of transport fuel use, nevertheless biofuel provide some optimism for reducing high oil import dependency and help in addressing security of supply concerns to some extent. Brazil is the world's biofuel leader, in 2005, its ethanol share in light-vehicle fuel demand increased to about 37 percent (equivalent to 10.5 billion liters) compared to 33 percent in the previous year. Such overwhelming initiatives are also needed to be taken by other agricultural based economies in an attempt to reduce energy import dependency to certain extent. The developing countries must take the benefit of Brazilian learning curve as the country's cost of ethanol is 50 percent lower than US. In the United States, 15 percent of the corn crop provides about 2 percent of the non-diesel transport fuel, ethanol production is growing even more rapidly. Biofuels could replace 20–30 percent of the oil used in European Union countries during the next 50 years. The production of biofuels not only increases energy security, creates new economic opportunities in rural areas, but also reduces local pollution and emissions of greenhouse gases. For example, the ethanol industry provides 200,000 jobs in the United States and 500,000 jobs in Brazil, which produces slightly more ethanol than the United States[9].

Biofuels are an attractive option for least developed and highly populated energy deficient economies of Africa and Asia as they can help provide economic incentives – creating jobs, availability of energy, which in turn would lead to improved quality of life. The only problem is that in some of the developing countries people are living in extreme poverty. Therefore, the only caveat is that government incentives should not be used to minimize competition between food and fuel crops and to discourage expansion onto ecologically valuable lands. The significant expansion and large land utilization for the production of sugar cane, soybean and other crops for the production of biofuel is likely to create global shortage of food crops, leading to impact on prices. For example, in Brazil and Asia, fields of soybeans and palm, whose oils have the potential to become significant sources of biodiesel, are encroaching on tropical forests, which hold great wealth's of biodiversity. Such options need to be carefully considered, as the immediate problem is to produce agricultural produce to feed millions of people. For such economies, other renewable sources of energy options should be explored like solar and wind energy as a first step. The developed countries and the international donor agencies, such as, World Bank, Asian Development Bank and other regional banks should provide resources and technology to address long-term needs of these economies.

For the purpose of electricity generation, a number of renewable sources of energy are available and are being effectively used mostly by developed countries. For example, solar, wind, geothermal, tidal, bioenergy, hydroelectric is the renewable forms of energy that are being used for electricity generation. Apart from high cost all forms of energy are having some advantages and disadvantages. Presently Japan, Germany and USA are the leaders in the production of electricity using solar energy respectively

[9] According to Worldwatch Biofuels Project Manager Suzanne Hunt.

producing 1132, 794 and 365 MW in 2003. The only constraint is high cost of solar cells, reliability but having advantages that it would be useful in remote location and useful for heating and lighting. Germany is the leader in wind electricity generation with a capacity of 16,649 MW, Spain (8263), USA (6750). Other countries are Denmark, India, Italy, Holland, Japan, UK and China. The leaders in bio-energy are USA (6115 MW), Sweden (1670), Finland (1500) and other European countries. Geothermal based energy is mainly situated in the developed countries – with USA 2133 MW, Mexico 960, Italy 707, Japan 535 MW and some other countries in Europe. Renewable sources of energy have considerable potential for developing countries, particularly in Africa and Asia - most of the countries in these regions do meet the pre-requisites for benefiting from renewable sources of energy to reduce their import dependency and also to increase accessibility and efficiency of the available energy supplies for positively impacting the quality of life of the resource poor consumers. There are challenges, including high costs and institution and policy level constraints. However, with improvement in technology and the policy environment over time, improvements are likely to emerge with better access and availability of energy supplies. Combination of investment in fossil fuel and renewable sources of energy is critical and requires continued support to ensure increase in energy supplies and its access to all segments of societies, including those in developing countries. The share of renewable energy sources is set to increase in the coming years that in turn may help in reducing the burden on fossil fuels to some extent and facilitate shifting the projected TPEC demand curve downward. International disputes should be resolved to reduce the uncertainty in energy prices as well as create conducive investment environment for the expansion in energy supplies.

Summary

In 2004, eighteen countries are either major holder of natural resources, major producers, consumers or combination of the three. African and Asia Pacific developing consumers on per capita total primary energy consumption (TPEC) basis consume equivalent of about 5.6 and 9.6 percent respectively of what North American consumers consumed in 2003. This uneven distribution of oil, natural gas and coal has led to wide regional disparity and to some extent explains the wide gap between the rich and poor nations.

The paper reviews the historical trends and distribution of natural resources and makes an attempt to forecast the regional TPEC to 2050 under alternative scenarios. The purpose here is to provide most probable path so that appropriate policies and measures be taken to enhance and slow down the energy consumption without hampering the economic growth. Global TPEC most likely to reach within the range of 763-1259 Quadrillion Btu (QBtu) to 2050 with reference case trending between the two and stood at 978 QBtu. By 2050 the equation of TPEC is expected to be tilted in favor of developing countries when their share increases from 47 percent in 2003 to 59 percent. By 2050, Asia developing region becomes the largest consumer of TPEC surpassing the dominance of North America. However, on a per capita basis the region remains the lowest after Africa. Per capita TPEC in Middle East and Central and South America is expected to increase significantly. The purpose here is to give some guidance to policy makers for taking timely appropriate investment decisions to augment energy supplies and address some of the policies issues. What policy reform measures should be taken to ensure availability of predicted level of energy resources? How to mobilize sizeable investment to increase the expected production capacity and logistic support both in the producing and consuming countries? Simultaneously what strategic measures are needed to be taken now: to improve the energy efficiency, energy conservation, development and promotion of renewable sources of energies and check population growth in an effort to downward shift the probable TPEC path without compromising the economic growth, productivity and quality of life?

The message of this paper is addressed to both the developing and developed countries' policy makers. It is the responsibility of the government and people of poorly endowed least developing countries to develop transparent policies, maintain stable law and order environment - conducive for investment in the energy sector and also to take measures to check their population growth rate (the objective of checking and slowing down the population growth is to rationalize and balance energy utilization to ensure efficiency and accessibility to a large population at an affordable rate). The responsibility of developed countries and multinational energy companies on the other hand is to make an appropriate investment in exploration and development of energy resources and transfer of technology including renewable sources in an effort to reduce the regional disparity and improve the quality of life of masses.

Combination of investment in fossil fuel and renewable sources of energy is critical and requires continued support to ensure increase in energy supplies and its access to

all segments of societies, including those in developing countries. The share of renewable energy sources is set to increase in the coming years that in turn may help in reducing the burden on fossil fuels to some extent and facilitate shifting the projected TPEC demand curve downward. International disputes should be resolved to reduce the uncertainty in energy prices as well as to create conducive investment environment for the expansion in energy supplies.