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The Contribution of Energy Consumption to Climate Change: A Feasible Policy Direction

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ABSTARCT: Mitigating climate change is one of the biggest challenges that confront mankind in the present millennium. The problem has continued to dominate public debates in terms of its origin, sources, potential impacts and possibly adaptation strategies. In this paper, the contributions of energy to the climate change debate are explored. The analysis shows that since about 1850, the global use of fossil fuels (coal, oil and gas) has increased and dominated world energy consumption and supply. The rapid rise in fossil fuel combustion has produced a corresponding rapid growth in CO_2 emissions and accounts for over 80% of global anthropogenic green house gas emissions (GHGs) in 2008. It was shown that a substantial amount of CO_2 emissions still emanates from the increased use of heavy polluting fuel like coal by industrializing countries like the United States, Japan and China. Historically, the developed countries have contributed the most to cumulative global CO_2 emissions and still have the highest total historical emission. A disaggregated analysis indicates that two sectors of the economy, electricity and heat as well as the transport sector (majorly road transport), emit greater amounts of GHGs. Some mitigation mechanisms have been suggested including improved energy efficiency, energy pricing reforms, imposition of carbon emission taxes, promoting investment in renewable energy technologies and creating public environmental awareness.

Keywords: Climate change; Fossil fuel; CO_2 emissions
JEL Classifications: Q40, Q20, Q32

1. Introduction

Energy is and will continue to be a primary engine for economic development. It is central to achieving the goals of sustainable development. Socio-economic development requires energy for improved living standards, enhanced productivity, effective transportation of goods to the point of need, and as inputs to a wide range of economic production activities. Energy represents material comfort to industrialized countries, but the way to alleviation of poverty in developing countries. The three last centuries have seen mankind's substantial dependence upon an ever-growing use of fossil fuels (coal, oil and gas) for industrialization and urbanization (Cao, 2003; Reddish and Rand, 1996). However, the exploitation of energy to drive the growth process of many nations comes with increasing costs of environmental pollution. Potentially, the most important environmental concern in the last decade relates to its impact on global change in weather, also known as global warming or the greenhouse effect. Climate change is the long-term, significant change in the patterns, glaciations and related aspects of the global climate system. Thousands of researchers and policy makers across the world have been piecing together an increasingly irrefutable case that climate change is an immediate threat to mankind's survival and sustainable development.

Mitigating the impact of climate change has dominated most public discourse not only by environmental economists but also by other environmental experts and scientists. Many experts attributed the root cause of climate change to human activities that comes with the rapid growth of the global economy including human consumption of different sources of energy, rapid rate of

deforestation and bush burning. The effects of energy consumption combustion are evaluated as greenhouse effects resulting from emissions of environmental pollutants such as carbon monoxide, hydrocarbon compounds, sulfur oxides, nitrogen oxides, methane and the particulates. Amongst several pollutants causing climate change, a great deal of attention has been given to CO_2 emission as the major factor in the climate change. While the impact of other forms of air pollutants is primarily local or regional, CO_2 emissions are, above all else, global in scale. Sources of CO_2 emission often cited in the literature include the energy related component, especially, the combustion of fossil fuels. Others include the non-fuel use of energy inputs, and emissions from electricity generation using non-biogenic municipal solid waste and geothermal energy, emissions from industrial processes, such as cement and limestone production, etc.

This paper is concerned with the contribution of energy to the climate change debate. In this connection, some useful questions could be raised: To what extent is energy responsible for CO_2 emission? Which form of energy is chiefly responsible for the energy-related climate change? What sectors of the economy drives these energy-related CO_2 emissions? What are the viable options for mitigating energy-related climate change? These and other similar questions are addressed in this paper. The structure of this paper is the following. In the next section, we undertake a brief review of the origin of the climate change debacle. Next, we examine the role of energy to climate change. Thereafter, we outline some policy options for mitigating climate change. The last section provides the conclusion to the paper.

2. Climate Change in Historical Perspective: How Did We Get Here?

The phrase "climate change" and "global warming" and more recently "global cooling" is increasingly assuming a topical dimension in global climatic and environmental discourse. Rarely does a day go by without a mention in the press or on the radio of the possible causes of climate change and its consequences. The threat of climate change has come upon mankind in a relatively short space of time and is accelerating with an alarming speed. It is one of the most challenging problems with which our contemporary world has been faced. It has become a subject of major international co-operation through the Intergovernmental Panel on Climate Change (IPCC) which was set up in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme. Unfortunately, most climate change debate often lack historical perspective. To get a better sense of the problem, it might be instructive to pose the question: how did the world get to where they are today?

According to Girardet and Mendonca (2009:26), the origin of climate change can be traced to the impact of human activities that started about 300 years ago. The authors argued that in 1709, the first blast furnace was built in Coalbrookdale, Shropshire, Britain which used coke, derived from coal, rather than charcoal derived from wood, for smelting iron ore. The new coke-smelted iron proved to be superior in energy production as well as cheaper financial outlay, making coke-furnace melting process preferable to the charcoal-furnace process. Crucially, it is argued that the inexpensive cast iron helped to trigger the start of the industrial revolution in Britain – a self accelerating chain reaction of industrial and urban growth based on ever greater refinements in fossil-fuel-based technologies. The potential catastrophic environmental consequences of the ever-increasing use of coal were largely ignored.

In 1711, the first steam engines, made with cast iron, started to pump water out of British mines that were up to 50 meters deep (Girardet & Mendonca, 2009:26). These pumping engines enable miners to dig ever deeper to extract minerals from the earth's crust. Furthermore, Girardet and Mendonca (2009:27) revealed that sixty years later:

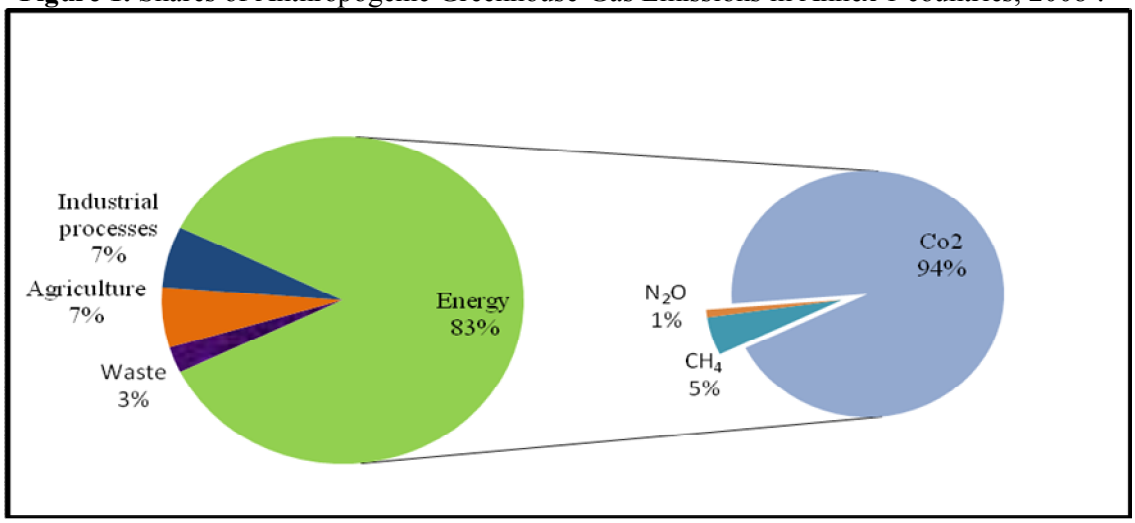
> *The firm of Boulton & Watt introduced the next generation of steam engines and by 1800 over 500 were in use, first in mines and then to drive machinery in factories. In 1830 steam locomotives were used to pull passenger trains for the first time, and in 1845 the first steam-powered ship, the SS Great Britain, triggered a revolution in the mass transportation of goods and people across the oceans.*

It must be noted that until the early 18th century, muscles (human power), firewood and charcoal were the dominant sources of energy, augmented by the limited use of water and windmills, with human lifestyles dependent on living within nature's productive capacity. But as the industrial revolution unfolded, the dramatic increase in the use of coal, and then oil and gas, not only massively increased human productive power and mobility but was also a major contributor to the ten-fold growth in human population, from some 700 million in 1709 to nearly 7 billion today (Girardet and Mendonca, 2009:27). The industrial revolution powered by an increased coal production in Britain transformed the human presence on earth. It gave humanity unprecedented powers to exploit the riches of nature – cutting down forests, clearing new farmlands, accelerating industrial production, extending transportation systems, building new cities and expanding existing ones. By 1890s, the U.S. overtakes Britain as the world's leading industrial nation and has continued to spread across the world. Today, Japan, Korea, Brazil, Mexico, Venezuela, China, India and South Africa are on their path to becoming major industrial nations in their own right. China's industrial boom, for instance, is linked to a rapid increase in domestic energy consumption with millions of cars manufactured yearly. Cars run on oil based fuels: by 2020 China is expected to import much of its oil. China's coal consumption, mainly in power station, is going up in similar rate. According to the 1992 World Bank projections, world population will more than double by 2150, with two thirds of the increase projected to occur by 2050 (World Bank, 1992:70). High population growth and increased urbanization invariably will lead to increased demand for energy, implying increased expected environmental damage as well.

3. The Role Energy in the Climate Change Debate

Worldwide economic growth and development require energy. The increased concentrations of key greenhouse gases (GHGs) are direct consequences of human activities. Since anthropogenic GHGs accumulate in the atmosphere, they produce net warming by strengthening the natural "greenhouse effect". Specifically, energy production and consumption have various environmental implications, one of which is climate change. Among the many human activities that produce GHGs, the use of energy represents by far the largest source of emissions as shown in Figure 1.

Figure 1. Shares of Anthropogenic Greenhouse-Gas Emissions in Annex 1 countries, 2008[1].



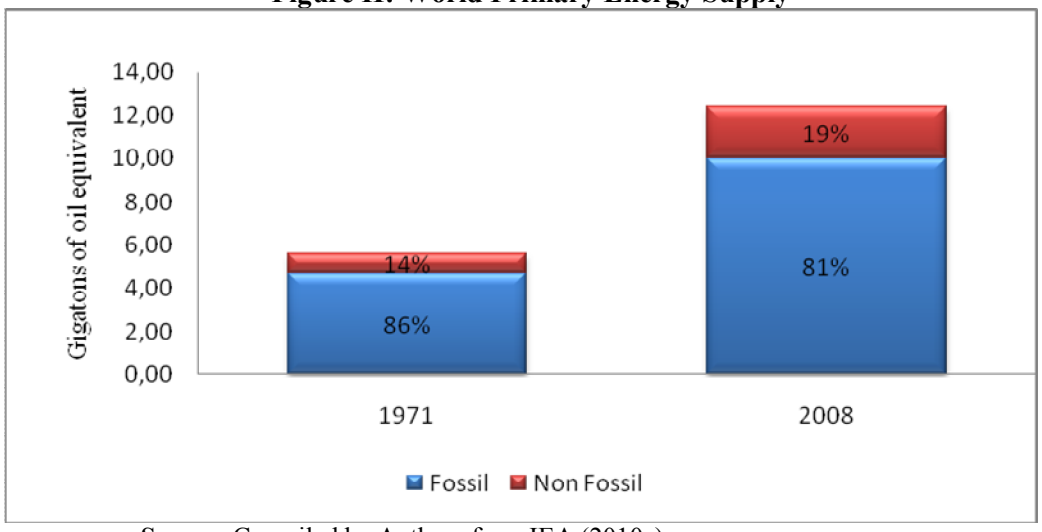
Source: Captured by Authors from UNFCCC cited in IEA (2010a)

[1] **Annex I Countries** include Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and the United States.
The countries that are listed above are included in Annex I of the United Nations Framework Convention on Climate Change as amended on 11 December 1997 by the 12th Plenary meeting of the Third Conference of the Parties in Decision 4/CP.3. This includes the countries that were members of the OECD at the time of the signing of the Convention, the EEC, and fourteen countries in Central and Eastern Europe and the Former Soviet Union that are undergoing the process of transition to market economies.

As shown above, energy accounts for over 80% of the global anthropogenic GHGs, with emissions resulting from the production, transformation, handling and consumption of all kinds of energy commodities. The key information in Fig. 1 is the fact that energy use emissions are predominantly responsible for CO_2 emissions. Smaller shares correspond to agriculture, producing mainly CH_4 and N_2O from industrial processes not related to energy, producing mainly fluorinated gases and N_2O. GHG emissions from the energy sector are dominated by the direct combustion of fuels, a process leading to large emissions of CO_2. A by-product of fuel combustion, CO_2 results from the oxidation of carbon in fuels (IEA, 2010a)[2]. Responsible for about 94% of the energy-related emissions, CO_2 from energy represents about 83% of anthropogenic GHG emissions for the Annex 1 countries (Fig. 1) and about 65% of global emissions (IEA, 2010a). This percentage varies greatly by country because of diverse national energy structures and policies.

A key factor responsible for the higher energy-related emissions cum climate change challenge is the increased global reliance on primary energy supply to drive economic growth and development. As illustrated in Fig. II, global total primary supply (TPES) doubled between 1971 and 2008, primarily relying on fossil fuels. In other words, fossil fuels still account for most of the world energy supply. The figure shows that in-spite of the growth of non-fossil energy (such as nuclear and hydropower) which are usually considered as non-polluting, fossil fuels have continue to maintain their dominance in TPES for the past 37 years under review. In 2008, it accounted for 81% of the TPES in the world.

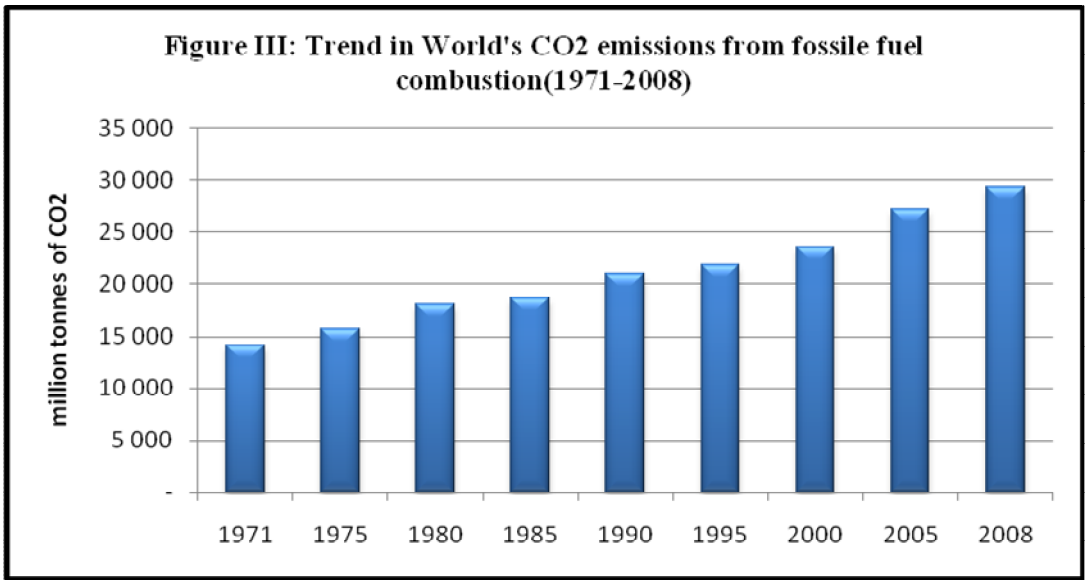
Figure II: World Primary Energy Supply[3]



Source: Compiled by Authors from IEA (2010a).

The high global dependence upon fossil fuels clearly is responsible for the observed upward trends in the global CO_2 emissions, as illustrated in Fig. III. Since the industrial revolution, CO_2 emissions from fuel combustion have witnessed a dramatic increase from its near zero level in the 1870s (See Quadrelli and Peterson, 2007, IEA, 2010a) to about 29.4 million tons by 2008 (Fig. III). The figure shows that CO_2 emissions from fossil fuels combustion in 2008 were roughly twice its level in 1971. Depending, upon one's forecast of the growth of fossil fuel combustion, one can project a doubling of the CO_2 concentration in the next 50 to 300 years.

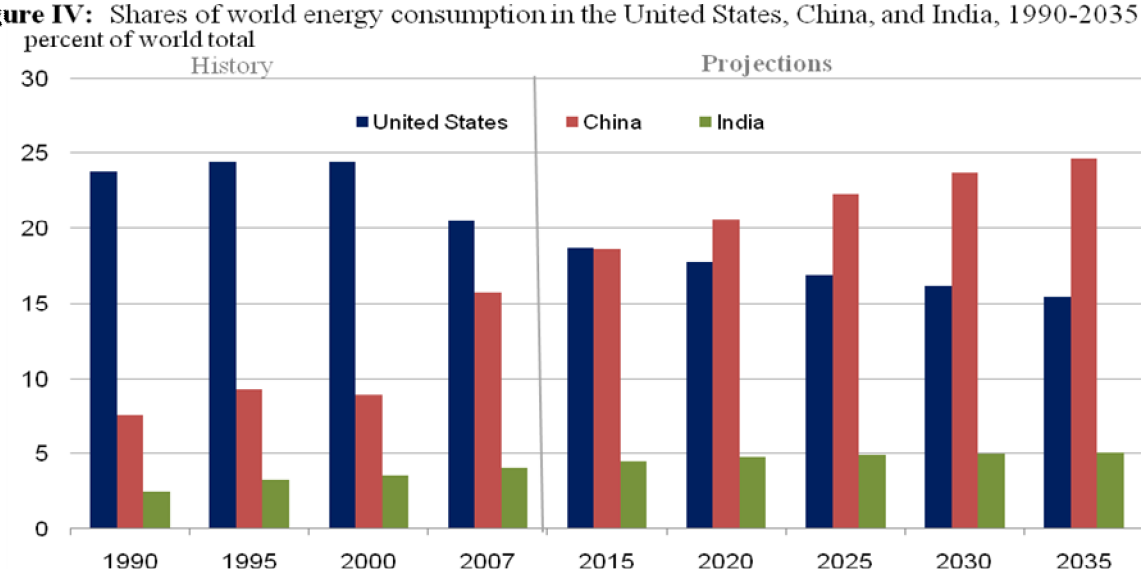
[2] In perfect combustion conditions, the total carbon content of fuels would be converted to Co2 (See Quadrelli & Peterson, 2007).
[3] Figures include International bunkers.



Source: compiled by Authors from IEA (2010b).

Meanwhile, total global energy supply is projected to rise by 52% between 2008 and 2030 (IEA, 2010a) and with fossil fuels remaining at 81% of TPES, CO_2 emissions are consequently expected to continue their growth unabated (unless some drastic measures are taken) and will reach 40.4 Gt CO_2 by 2030 (Ibid). The trend is expected to be intensified due to the projected high increase in world energy consumption demand by industrializing country like China (see Fig. IV). Presently, the figure shows that the United States still dominates world energy consumption followed by China and India and doubtless the higher emitters of CO_2 energy-related emissions (see Fig. VI). It is projected that the shares of China in world energy consumption would outstrip that of the United States by the year 2020. Whether the projections will be a possibility or not, it is obvious that the socio-economic and technological characteristics of development paths of the industrializing countries will strongly affects energy-related emissions and hence, the rate and magnitude of climate change, climate change impacts, the capability for adaptation and mitigation of climate change emissions.

Figure IV: Shares of world energy consumption in the United States, China, and India, 1990-2035

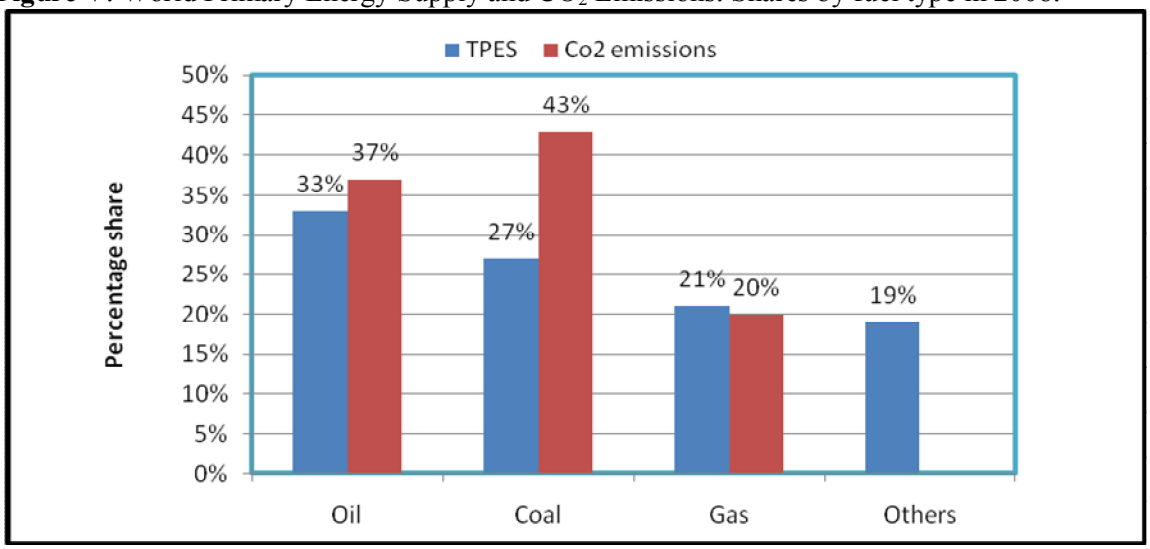


Source: IEA, International Energy Statistics database (as of November 2009), available at: www.eia.gov/emeu/international.

4. Energy Contribution to Climate Change: A Further Disaggregated Analysis

It may be important to further disaggregate the sources of energy-related CO_2 emissions. Available data on the contribution of fuel to global CO_2 emissions as at 2008 is shown in Fig. V. It can be seen that although coal represents only one-quarter of the world TPES in 2008, it accounted for 43% of the global CO_2 emissions due to its heavy carbon content per unit of energy released. Compared to gas, coal is on the average nearly as twice emission intensive[4]. Without additional measures the supply of coal is projected to grow from 2775 million tons of oil equivalent (Mtoe) in 2004 to 4441 Mtoe in 2030 (Quadrelli and Peterson, 2007). In the future, coal is therefore expected to satisfy much of the growing energy demand of emerging developed countries like China and India, where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources (Quadrelli and Peterson, 2007). In addition, in spite of the deplorable environmental consequences, coal's appeal may rise as prices of oil and natural gas increase, consequent to growing demand and pressure on the reserves of these two fuels. This will further worsen the environmental pollution.

Figure V: World Primary Energy Supply and CO_2 Emissions: Shares by fuel type in 2008.



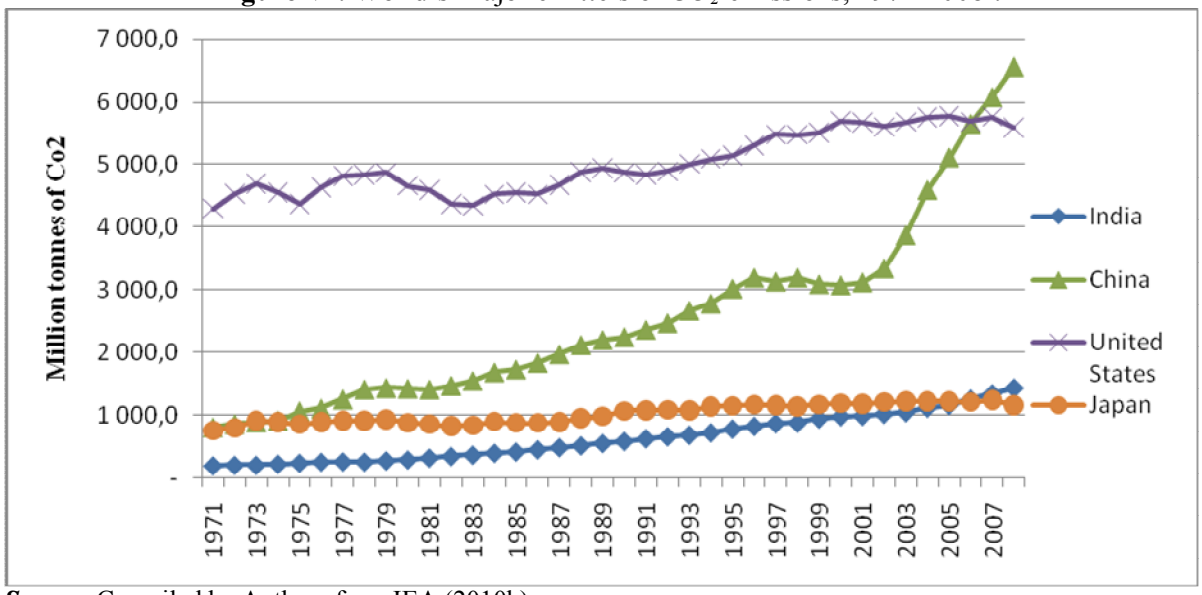
Source: Compiled by Authors from IEA (2010a).
Note: Others include nuclear, hydro, geothermal, solar, tide, wind, combustible renewable and waste.

Figure VI shows the contributions of the four largest carbon emitters in the world between 1971 and 2008. Although the United States remained the largest CO_2 emitter up to 2007, its contribution is relatively stable over time. However, the rate at which it grows in India and in particular China is worrisome. In fact, China overtook the United States in 2007 as the world's largest annual emitter of energy-related CO_2, although as shown by IEA (2010a) the United States will still remains the largest in many years to come in terms of cumulative and per capita terms (see further evidence in Table1). In other words, it has been argued that China's emission rate of CO_2 is important to significantly affect world indicators. Quadrelli and Peterson (2007) have shown that the rise in China's per capita emissions (+17%) causes global emissions to rise by 4%. It is important to note that fossil fuels represents more than 80% of China's energy mix; the country draws more than 60% of its energy supply from coal alone (IEA, 2010a). Fig. VII which presents the historical trends in the energy mix and their consequent contribution to the present global change debacle is very illuminating on this. Some points are clear from the figure. First, The United States, through the use of coal in the early 19th century, contributed the largest emission to the current problem. During the 20th century, it is also evident that a substantial amount of CO_2 emissions still emanates from the increased use of coal by the United States, Japan and China. It is also confirmed that China's heavy reliance on coal is

[4] See further evidence in IEA (2010a) for the IPCC default carbon emissions factors from the *1996 IPCC Guidelines* which are 15.3 t C/TJ for gas, 16.8 to 27.5 t C/TJ for oil products and 25.8 to 29.1 t C/TJ for primary products.

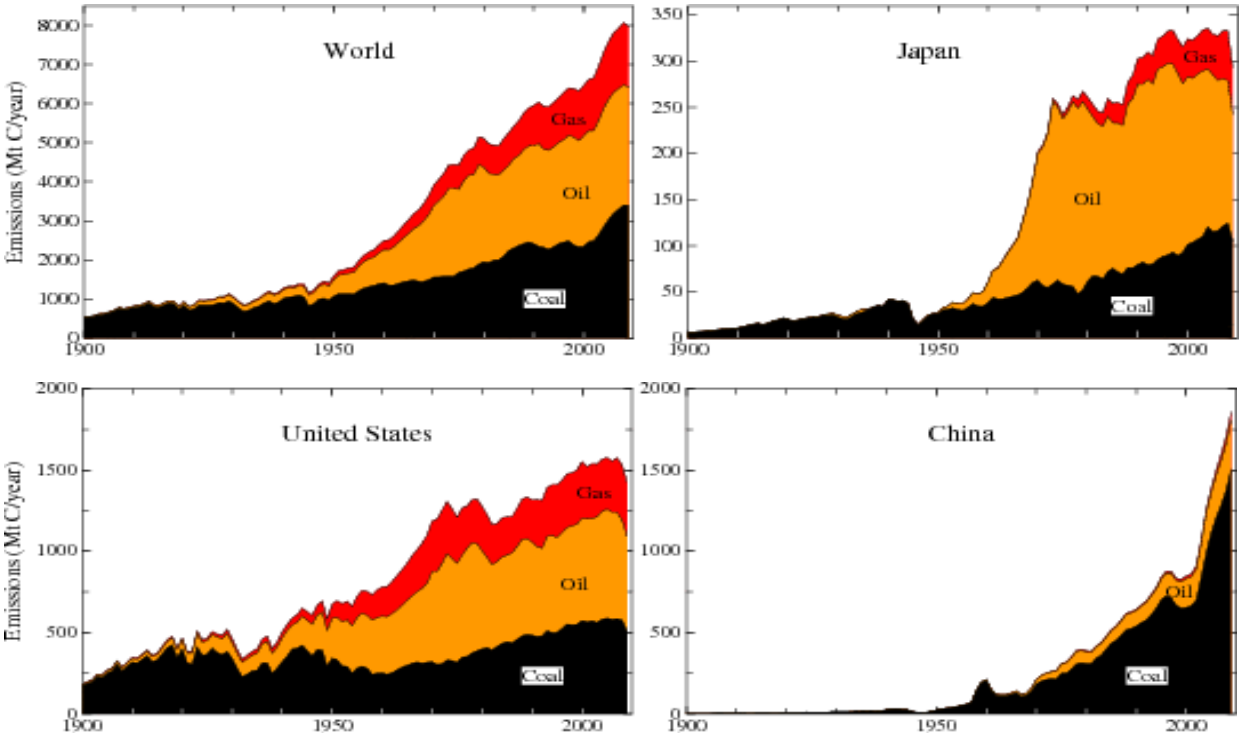
responsible for most of the observed CO_2 emissions in the world (see evidence in Table 1). The contribution of gas to global CO_2 emission is shown to be minimal. However, the same cannot be said about oil, especially from the 1950s with more of it coming from the United States followed by Japan.

Figure VI: World's Major emitters of CO_2 emissions, 1971-2008[5].



Source: Compiled by Authors from IEA (2010b).

Figure VII: Historical Trends in fossil fuel emission in the World, United State, China and Japan.



Source: *Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory and British Petroleum available at* http://www.columbia.edu/~mhs119/UpdatedFigures/

[5] The ten top CO_2 emitting countries in the world as at 2008 were China, United States, Russian Federation, India, Japan, Germany, Canada, United Kingdom, Islamic Republic of Iran and Korea, in that order. These ten countries account for 19.1 Gt CO_2 out of the world's 29.3 Gt CO_2 in 2008 (see Fig. A1 at Appendix).

As shown also in Table 1, the percentage shares of the developed countries in global world emissions are unambiguously larger than the corresponding shares in Africa, the Middle East and non-OECD countries. For instance in 2008, OECD North America alone constitutes over 17% of global CO_2 emissions from Coal, 26% from oil and 26% from Gas combustion. These contrast remarkably from the shares of world emissions by Africa which stood at about 2%, 4% and 3% respectively for coal, oil and gas combustions.

Table 1. CO_2 Emissions (in million metric tons) by World Regions and Fuel Types (1971-2008)

	COAL				OIL				GAS			
million tonnes of CO_2	1971	% Share	2008	% Share	1971	% Share	2008	% Share	1971	% Share	2008	% Share
World	5 199	100	12 595	100	6 838	100	10 821	100	2 058	100	5 862	100
United States	1 078.7	20.7	2 085.7	16.6	2 023.0	29.6	2 227.3	20.6	1 189.5	57.8	1 257.5	21.45
OECD North America	1 145.6	22	2 228.7	17.7	2 304.6	33.7	2 755.2	25.5	1 277.6	62.1	1 545.1	26.4
OECD Pacific	292.7	5.6	880.5	7	663.2	9.7	840.7	7.8	12.9	0.63	348.0	5.9
OECD Europe	1 690.1	32.5	1 214.5	9.6	1 756.2	25.7	1 676.0	15.5	191.1	9.3	1 055.5	18
Middle East	0.8	0.02	33.8	0.3	102.5	1.5	850.2	7.9	25.8	1.25	608.2	10.4
Non-OECD Europe	101.4	1.95	130.1	1	91.1	1.3	90.6	0.8	54.8	1.3	47.1	0.8
Latin America	22.7	0.44	92.9	0.74	302.2	4.4	714.4	6.6	41.6	2	260.9	4.5
Asia	231.9	4.5	1 548.5	12.3	192.0	2.8	1 026.8	9.5	10.2	0.5	445.3	7.6
China	678.0	13	5 460.8	43.4	124.2	1.8	934.8	8.6	7.3	0.35	154.9	2.6
Africa	160.7	3.1	304.3	2.4	99.7	1.5	407.8	3.8	5.2	0.25	177.8	3

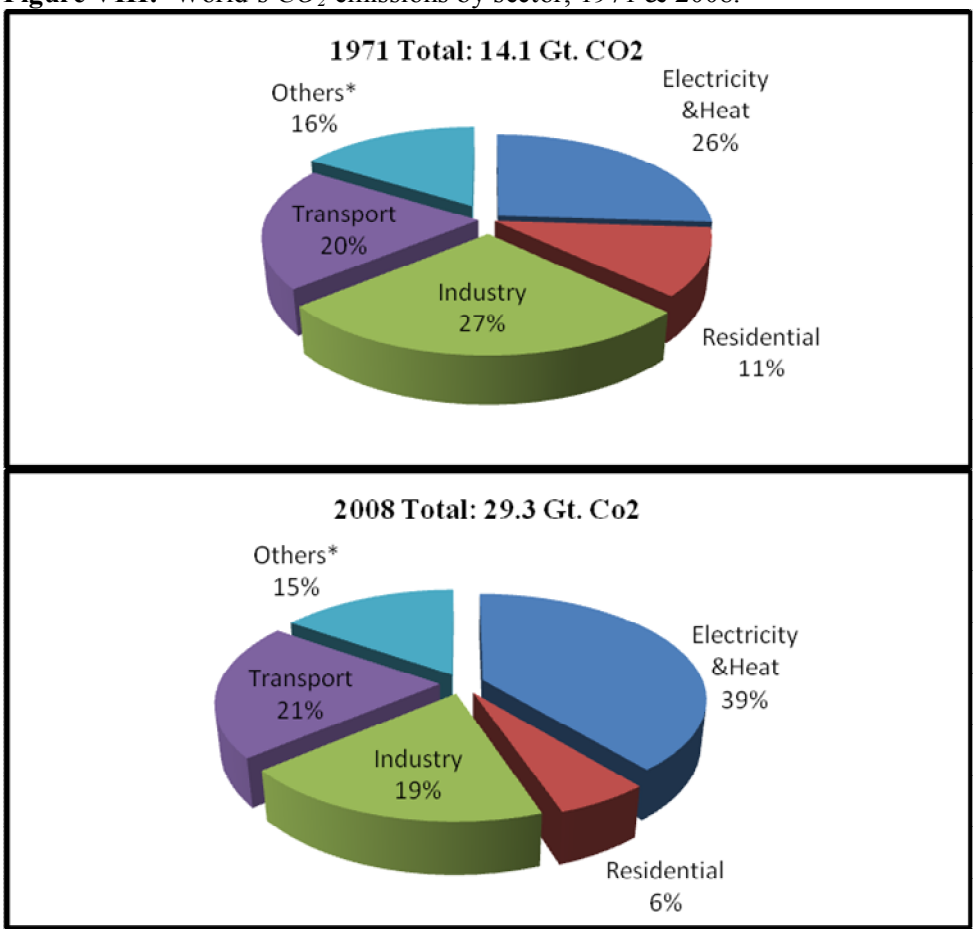
Source: Authors' Computation from IEA (2010b).

In terms of emissions by sector, Fig VIII presents a very informative picture. Three sectors, electricity and heat generation, industry and transport are chiefly responsible for the global CO_2 emissions. Between the two periods under review, whereas the shares of the emissions from the industrial and residential sectors decline, there was growth in emissions from the electricity and heat sector as well as the transport sector. The decline in the emissions from the other two key sectors may be an indication of significant improvements in energy efficiency and other fuel switching efforts in most developed countries over the years.

Generation of electricity and heat was by far the largest producer of CO_2 emissions and was responsible for 39% of the world CO_2 emissions in 2008. Globally, evidence (from IEA, 2010a) indicates that this sector is noted for its heavy reliance on coal, the most carbon-intensive of fossil fuels and thus amplifying its share in worldwide emissions of CO_2. For instance, countries such as Australia, China, India, Poland and South Africa are estimated to generate between 69% and 94% of their electricity and heat through the combustion of coal (see IEA, 2010a). The transport sector on the other hand, relies heavily on oil and over 80% of the emissions from the transport sector in 2008 are driven by road transportation (see Appendix, Table A1)[6]. Clearly, this end-use sector is the strongest driver of world dependence on oil. Global demand for transport is forecast to grow by 58% by 2030 (IEA, 2004) and hence bears significant implication for worldwide oil related emissions.

[6] A key factor in this development could be attributed to the effect of economic growth on increasing demand for road transportation, both for personal mobility and for transportation of goods. Car ownerships in most developing countries tend to grow with increasing income per capita following growth.

Figure VIII: World's CO_2 emissions by sector, 1971 & 2008.



Source: Quadrelli & Peterson (2007) and Author's compilation from IEA (2010b), available at www.iea.org/statistics/

Note: *Others include commercial public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.

5. The Energy-Climate Change Challenge: Options for Mitigation

It has been clear from the preceding sections that the link between energy and climate change is very strong and thus constitutes a significant challenge for sustainable development. The negative impacts of climate change on crop production, higher average world temperature, rising sea levels, reduced rainfall, amongst others are largely indisputable in the literature. However, efforts to combat the disaster both at the international, regional or national level could at best be describe as less than successful. For instance, at the global level, implementing the various mitigation measures under the Kyoto Protocol of the UNFCCC has yielded limited results in its potential to address global CO_2 emissions. For one, not all the major emitters were included (see IEA, 2010a for details on this)[7]. On the other hand, developing countries, though most signed the protocol are less committed to CO_2 emission reductions. A key policy dilemma faced by most developing countries is in balancing the tradeoff between sustained economic growth and reducing CO_2 energy-related emissions. The thinking in many quarters is that CO_2 emissions is a global pollutant and thus curtailing it by one country is practically proving difficult and inefficient to do since elements of market failure are predominant. If one country cuts its rate of fuel combustion, it bears the full cost in terms of reduction in its economic activity level, while the benefits of its action are shared with the entire world. This has lead some analysts to suggest that the effort towards CO_2 mitigation should be pioneered and borne by the industrialized countries who are not only responsible for the initial emissions of CO_2 during the

[7] For instance a major CO_2 emitter country like the United States has expressed the intention not to ratify the Kyoto Protocol.

industrial revolution but also for the increased level of emission as a result of growing consumption of fossil fuel.

However, irrespective of whatever divide, effective mitigation of climate change will require the effort of all countries. An optimal strategy for mitigating the consequences of climate change that arise from energy –related activities would not only need to be highly comprehensive and global in scale, but such policies would have to be flexible and adaptable to national and local conditions of the given nation. Box 1 presents an overview of some available policy instruments.

Box 1: An Overview of Climate Change Policy Instruments

***Regulations And Standards*:** Specify abatement technologies (technological standards) or minimum requirements for pollution output (performance standards) to reduce emissions.

Taxes and Charges : A levy imposed on each unit of undesirable activity by a source

***Tradable Permits* :** Also know as marketable permits or cap-and-trade systems, this instrument establishes a limit on aggregate emissions by specified sources, requires each source to hold permits equal to its actual emissions, and allows permits to be traded among sources.

***Voluntary Agreements* :** An agreement between a government authority and one or more private parties to achieve environmental objectives or to improve environmental performance beyond compliance to regulated obligations. Not all voluntary agreements are truly voluntary; some include rewards and/or penalties associated with joining or achieving commitments.

***Subsidies and Incentives*:** Direct payments, tax reductions, price supports, or the equivalent from a government to an entity for implementing a practice or performing a specified action.

***Information Instruments*:** Required public disclosure of environmentally related information, generally by industry to consumers. Include labeling programs and rating and certification.

***Research and Development*:** Direct government spending and investment to generate innovation on mitigation, or physical and social infrastructure to reduce emissions. Include prizes and incentives for technological advances.

Non-climate Policies: Other policies not specifically directed at emissions reduction but that may have significant climate-related effects

It is important to note that irrespective of any policy choice, mitigating the impact of energy-related climate change will require four key considerations:

(i) **Environmental effectiveness** – the extent to which the policy meets its intended environmental objectives or realizes positive environmental outcomes
(ii) **Cost effectiveness** – the extent to which the policy can achieve its objectives at minimum cost to the society
(iii) **Distributional considerations** – the incidence or distributional consequences of the policy. Fairness and equity are dimensions of this though there are other dimensions to distribution.
(iv) **Institutional feasibility**- the extent to which a policy instrument is likely to be viewed as legitimate, gain acceptance, adopted and implemented (IPCC, 2007).

This means that there is no one-size-fit-all policy prescription to climate change mitigation. A combination of policy options is needed. In line with this, the following options are proffered:

(a) Energy Pricing Reform

In most developing countries, energy pricing are still based upon social and political justification rather than efficient market pricing principles. The World Bank estimates for 1993

showed that developing countries and transition economies spent more than $230 billion per year on subsiding energy (Cao, 2003). Energy products like coal in China, India, Poland and Turkey have been heavily subsidized (World Bank, 2000:25), just as Nigeria spends billions on petroleum subsidy. The implication of this has been inefficient use of energy as well as serving as a disincentive for controlling energy-related emissions. Efficient energy pricing will not only remove these price distortions but would sharply reduce the growth in energy consumption and could also cut world carbon emissions by 10% (see World Bank, 2000:41)[8].

(b) *Emission Taxes*

It is obvious that efficient pricing reforms that results in energy prices reflecting production may still be far from reflecting social cost. Emission taxes could prove useful in adjusting market prices to reflect externalities. A high taxes on carbon-intensive fuels like coal could reduce their consumption and hence carbon emissions. In Mexico, an application of gasoline tax, among other measures, has helped to dramatically reduced GHG emissions coming from transportation (World Bank, 1992:74). Given the high level of energy-related emissions that comes from transportation, a policy of congestion pricing or taxes may be necessary. Motorists driving through city rush-hours traffic should be required to pay more than those driving in the rural settings or in off-peak hours[9].

The problem associated with minimization of CO_2 and other green house gas emissions through tax controls is that it has not fully appreciated, or given answer to, the question of final resting place of the incidence. The final bearers of such taxes may not be the industrial and transportation entrepreneurs; it may be the poor consumers who thus would end up with worse living conditions.

(c) *Promotion of Energy Efficiency*

Climate change mitigation via CO_2 reduction can be attained through more efficient energy use. Energy efficiency implies using less energy to provide the same services. For instance, replacing an old appliances such as a refrigerator or office equipments such as an old computer or printer with a more energy-efficient model provides the same services, but with less energy. This serves two purposes: a reduced energy bill and most importantly, a reduced amount of greenhouse gases emissions. It should be noted that "energy efficiency" is not the same as "energy conservation". Energy conservation is reducing or going without a service to save energy. For example turning off a light is energy conservation. Replacing an incandescent lamp with a compact fluorescent lamp (which uses much less energy to produce the same amount of light) is energy efficiency. The success of the promotion of energy efficiency largely depends on the adoption of energy efficient and low-emission technologies.

(d) Promotion of Investment in Renewable Energy

Ultimately, the mitigation of energy-related climate change rest upon the use of renewable energy including hydro, solar, wind, biomass and other forms of renewable , which are more environmentally friendly than conventional fuels (Cao, 2003). In many developing countries, there is a huge untapped and inefficiently utilized renewable energy resource which need specific national policy initiatives and international support, including finance, capacity building and technology transfer to be exploited. Environmental taxes on fossil fuels may be required to stimulate reactions in favor of renewable energy. Increased funding of R&D in renewable energy should also be pursued.

(e) *Improve Public Environmental Awareness*

Ignorance of the serious impact of their collective actions on climate change by the general public is an important cause of environmental damage and a serious impediment to finding solutions.

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[8] It is important to note that the removal of energy subsidies has always faced the problem of trade-off between worsening the level of poverty for the majority of the population and improving the environmental quality. Again, it is usually reasoned that one-stop removal of such subsidies may worsen the environmental problems because the affected poor may substitute poorer quality fuels for the cleaner but now (with removal of subsidies) dearer fuels.

[9] The problem with this is how cost effective it will be especially for developing countries with poor institutional capacities. A success story of such policy could be found in London where it has been applied to deal with its notorious traffic problem. In 2003, the city began levying a fee of £5 (about $9) for the privilege of driving into the center of the city during peak hours. Compliance is monitored by video cameras that identify the license plates of drivers who fail to pay the fee. Such drivers are then charged a substantial fine. The policy has help to reduce the number of vehicles on the streets of London by approximately 16% (Transport for London, 2007 cited in Rosen & Gayer, 2010:91).

Adequate environmental information is required to enlighten the public on the seriousness of the worsening environment they are living in, the costs to their health and quality of life. Such enlightenment would help to raise peoples' consciousness and enlist public support for environmental protection laws or policies. This could help to facilitate and augment official enforcement of environmental policies.

6. Conclusion

One of the major problems facing humanity in terms of achieving sustainable development is climate change. Many economic activities release greenhouse gasses – such as carbon dioxide, nitrous oxide and methane – that trap solar energy within the earth's atmosphere. The extra heat warms the climate, creating diverse economic, health, and ecological impacts. The paper explored the role of energy in the climate change disaster. Evidence has revealed that fossil fuels (coal, oil and natural gas) constitute the single largest human influence on the climate change debate, accounting for over 80% of the anthropogenic greenhouse emissions. It was shown that a substantial amount of CO_2 emissions still emanates from the increased use of coal use by industrializing countries like the United States, Japan and China. Historically, the developed countries have contributed the most to cumulative global CO_2 emissions and still have the highest total historical emission. Two sectors of the economy, electricity and heat as well as the transport sector (especially road transport) emit greater amounts of GHGs. Given the fact that primary energy still dominates the world energy mix, the potential goal conflicts between economic growth and environmental protection are rather obvious. Reducing energy-related carbon emissions may require reducing the amount of fossil fuel consumption and hence economic growth. This dilemma has tended to contribute to the slow global, regional and national actions in addressing the danger of climate change. However, the problem of climate change associated with increased fossil fuel combustion is serious and requires concerted and comprehensive solutions. Improving energy efficiency, reforms of inefficient energy pricing, imposition of carbon emission taxes, promoting investment in renewable energy and creating public environmental awareness are some of the mitigation strategies suggested in the paper.

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Appendix

Table A1: *CO_2* emissions from fuel combustion by Sector in 2008.

million tonnes of CO_2	**Total CO_2 emissions from fuel combustion**	**Electricity and heat production**	**Other energy industries****	**Manuf. industries and construction**	**Transport**	***of which: road***	**Other sectors**	***of which: residential***
World	**29 381.4**	**11 987.9**	**1 491.9**	**5 943.6**	**6 604.7**	**4 848.4**	**3 353.4**	**1 905.1**
Annex I Parties	*13 903.8*	*5 785.4*	*684.4*	*2 035.6*	*3 479.4*	*2 977.0*	*1 919.1*	*1 117.6*
Annex II Parties	*10 951.8*	*4 295.2*	*563.4*	*1 549.1*	*3 023.9*	*2 656.4*	*1 520.2*	*843.2*
North America	*6 146.8*	*2 522.7*	*333.5*	*730.9*	*1 853.5*	*1 582.7*	*706.2*	*373.6*
Europe	*3 222.9*	*1 063.9*	*164.4*	*514.3*	*850.5*	*790.6*	*629.8*	*402.8*
Pacific	*1 582.0*	*708.7*	*65.5*	*303.8*	*319.9*	*283.1*	*184.2*	*66.8*
Annex I EIT	*2 688.5*	*1 386.0*	*112.6*	*448.0*	*410.3*	*281.1*	*331.5*	*234.8*
Non-Annex I Parties	*14 444.6*	*6 202.5*	*807.4*	*3 908.1*	*2 092.3*	*1 871.4*	*1 434.3*	*787.6*
Annex I Kyoto Parties	*7 980.1*	*3 245.4*	*406.2*	*1 351.2*	*1 736.1*	*1 477.3*	*1 241.2*	*737.7*
OECD Total	**12 629.6**	**4 992.0**	**672.3**	**1 819.1**	**3 386.5**	**2 999.4**	**1 759.8**	**984.4**
Non-OECD Total	**15 718.8**	**6 995.8**	**819.6**	**4 124.6**	**2 185.1**	**1 849.0**	**1 593.6**	**920.7**

Source: IEA (2010b), available at www.iea.org/statistics/

Note

Annex II Parties include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States

Annex I Kyoto Parties include Australia, Austria, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom.

Membership in the Kyoto Protocol is almost identical to that of Annex I (see page 6), except for Turkey and Belarus which did not agree to a target under the Protocol and the United States which has expressed the intention not to ratify the Protocol.

Economies in Transition (EITs) are those countries in Annex I that are undergoing the process of transition to a market economy. This includes Belarus, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russian Federation, the Slovak Republic, Slovenia and Ukraine.

The **Organisation for Economic Co-Operation and Development (OECD)** includes Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.