



CARBON CREDIT OPTIMIZATION

A Thesis by

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DECLARATION

'I, OLUWAKEMI ADELE, declare that this dissertation is my own work. Any section , part or phrasing of more than 20 consecutive words that is copied from any other work or publication has been clearly referenced at the point of use and also fully described in the reference section of this dissertation.'

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ABSTRACT

Climate change effects are becoming overwhelming as its impacts are already unfolding in many parts of the world. Urgent action is therefore needed to ensure sustainable energy demands that will help in the reducing CO₂e emissions which are the drivers of climate change.

The research covers the evolution of the climate change establishments which brought about the birth of the Kyoto Protocol and its operations, the effects of electricity generation in Annex I and Parties to the Annex I and EIT countries, energy demand and population relation to the increasing levels of CO₂e emission in the developed and developing world, and the emergence of the voluntary carbon market as the fulcrum for carbon trading.

Currently, facts on electricity generation now show that EIT countries have surpassed the developed countries (Annex I and Parties to the Annex I) due to their growing energy demand and industrialization and this implies that developing world and Economies in Transition, will become a more attractive market for fossil fuel consumption than the developed countries that are now legally bound to reduce their emission.

In terms of TCO₂e emission, higher levels are still very much consumed per person in the developed countries and therefore a rapid shift to more renewable sources of energy, engaging new technologies like carbon capture and storage especially from coal-fired plants, setting carbon taxes, strong government domestic climate policy for each nation and the committed effort and social responsibility shown by companies to the environment in the nearest future may be saving option to limit the world temperature to 2°C or less by 2020.

The truth remains that the climate change reduction reality is a global effort that require the active participation of all countries regardless of energy demand or infrastructure.

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NOMENCLATURE

H ₂ O	Water Vapour
CO ₂	Carbon Dioxide
CH ₄	Methane
N ₂ O	Nitrous Oxide
CFCs	Chlorofluorocarbons
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF ₆	Sulphur Hexafluoride
GtCO ₂ e	Gigatonnes of carbon dioxide equivalent
°F	Degree Fahrenheit
°C	Degree Celsius
TCO ₂ e	One metric tonne of carbon dioxide equivalent
CO ₂ e	Carbon Dioxide equivalent
kgCO ₂ e	Kilogram of Carbon Dioxide equivalent
kWh	Kilowatt-hours
GJ	GigaJoules
MJ	MegaJoules
m ³	Cubic Meter
g	Grams
kg	Kilograms
g/mol	Molar Mass
Mol	Mole
kg/m ³	Density
Btu	British thermal unit

Toe	Tonne of Oil equivalent
kWh per Capita	Electricity (kWh)/ Population
TWh	Terawatt-hour

ABBREVIATIONS

GHG	Greenhouse Gases
GWP	Global Warming Potential
UNEP	United Nations Environment programme
NOAA	National Oceanic and Atmospheric Administration
UNFCCC	United Nations Framework Convention on Climate Change
Annex 1	Developed countries
Annex B	A document of climate change policies that includes the emission reduction targets of countries that have ratified the Kyoto Protocol.
ET	International emissions trading
AAU	Assigned Amount Units
JI	Joint Implementation
ERUs	Emission Reduction Units
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions Units
NGAC	New South Wales Greenhouse Gas Abatement Certificate
VCSs	Verified Carbon Standards
VERs	Verified Emission Reduction Standards
REC	Renewable Energy Certificate
BP	British Petroleum
COP	Conference of the Parties
Non- Annex 1	Developing Countries
WMO	World Meteorological Organisation
IPCC	Intergovernmental Panel on Climate Change
FAR	First Assessment Report of the IPCC
GMT	Global Mean Temperatures

SAR	Second Assessment Report of the IPCC
TAR	Third Assessment Report of the IPCC
NAPAs	National Adaptation Programmes of Actions
AR4	Fourth Assessment Report of the IPCC
CMP	Conference Meeting of Parties
RMU	Removal Unit
LULUCF	Land use, land-use change and forestry
G8	World leading industrialized economies
G20	Emerging transitional leading economies and regional capitals
OECD	Organisation for Economic Co-operation and Development
EIT	Economies in Transition
Annex II Parties	OCED members of Annex I only
EU ETS	European Union Emission Trading Scheme
EU	European Union
EUA	European Union Allocation
GDP	Gross Domestic Product
AFOLU	Agriculture, Forestry and Other Land Use
CGCF	China Green Carbon fund
NDRC	National Development and Reform Commission
IEA	International Energy Agency
Defra/DECC	Department for Environment, Food & Rural/ Department of Energy and Climate Change
U.S. EIA	United States Energy Information Administration
REDD	Reducing Emissions from Deforestation in Developing Countries
PAT	Perform, Achieve and Trade

CONVERSION TABLE

FOSSIL FUEL CONVERSION

Crude Oil	Tonnes (metric)	Kilolitres	Barrels	US gallons	Tonnes/year
Tonnes (metric)	1	1.165	7.33	307.86	-
Kilolitres	0.8581	1	6.2898	264.17	-
Barrels	0.1364	0.159	1	42	-
US gallons	0.00325	0.0038	0.0238	1	-
Barrels/day	-	-	-	-	49.8

Products	Barrels to Tonnes	Tonnes to barrels	Kilolitres to Tonnes	Tonnes to Kilolitres
LPG	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.24
Gas oil/ diesel	0.133	7.5	0.839	1.192
Residual fuel oil	0.149	6.7	0.939	1.065

Natural Gas	Billion cubic feet NG	Billion cubic feet NG	Million Tonnes Oil Equivalent	Trillion British thermal Units	Million barrels of Oil equivalent
1 billion cubic metres NG	1	35.3	0.90	35.7	6.60
1 billion cubic feet NG	0.028	1	0.025	1.01	0.19
1 million tonne of Oil equivalent	1.11	39.2	1	39.7	7.33
1 million tonnes LNG	1.36	48.0	1.22	48.6	8.97
1 trillion British thermal units	0.028	0.99	0.025	1	0.18
1 million barrels oil equivalent	0.15	5.35	0.14	5.41	1

Calorific equivalent

One tonne of Oil equivalent equals approximately:			
Heat Units	10 million kilocalories	42 gigajoules	40 million BTU
Solid Fuels	1.5 tonnes of Hard coal	3 tonnes of lignite	
Electricity	12 mega watts		

CHAPTER ONE

INTRODUCTION

1.1 THE SHIFT IN CLIMATE

The degrading and damaging effect of climate change is undoubtedly a crucial concern to this age and beyond as it affects the World's environment, economy, security and humanity. Predominant climate change factors include the greenhouse gases (GHG), volcanic and solar systems, aviation-induce contrails and cirrus changes, albedo effects and aerosol altering impact on clouds **Forster *et al.* (n.d)**; but of all these, GHG emissions including water vapour (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur Hexafluoride (SF₆) with global warming potential (GWP):- CO₂: 1, CH₄: 21, N₂O: 298, PFCs: 9,200, HFCs: 11,700, SF₆: 22,800 **Carbon Futures (2009)** largely resulting from human activities pose as the most threatening to climate change due to their rate of absorption and long term retention of thermal radiation from the sun resulting to increase in the earth's temperature .

The imbalance of the natural carbon cycle process as a result of the rise in atmospheric GHG emissions from natural and anthropogenic sources took an overwhelming turn with industrialization dating back to the year 1750 and current findings by the United Nations Environment programme (UNEP) estimates a catastrophic probable increase in emission levels to approximately 56 (GtCO₂e) by 2020 from 49.5gigatonnes of carbon dioxide equivalent (GtCO₂e) in 2009. This indication suggests that GHG's potency will continue to be the driving cause of climate change especially if atmospheric GHG emissions of 44(GtCO₂e) which could limit the world's temperature to 2°C or less is not reached by 2020 **UNEP (2010)**.

Further research carried out by the **National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (2012)** suggests that the 'effect of La Niña (exclusively represented by abnormal cold ocean temperatures) during boreal spring caused the soaring of average global temperature to 0.66°C (1.19°F) through land and ocean surfaces making May, 2012 the second warmest temperature in the one hundred and thirty-third (133) year record dipping slightly behind the 2010 warmth record by 0.05 °C (0.09°F) just a month after a year of the El Nino (represented by abnormally warm ocean temperatures) experience with average recorded temperatures of the northern and southern hemispheres at 0.85°C (1.53°F) and 0.47°C (0.85°F) respectively'. Figure 1 shows climate anomalies of May, 2012.

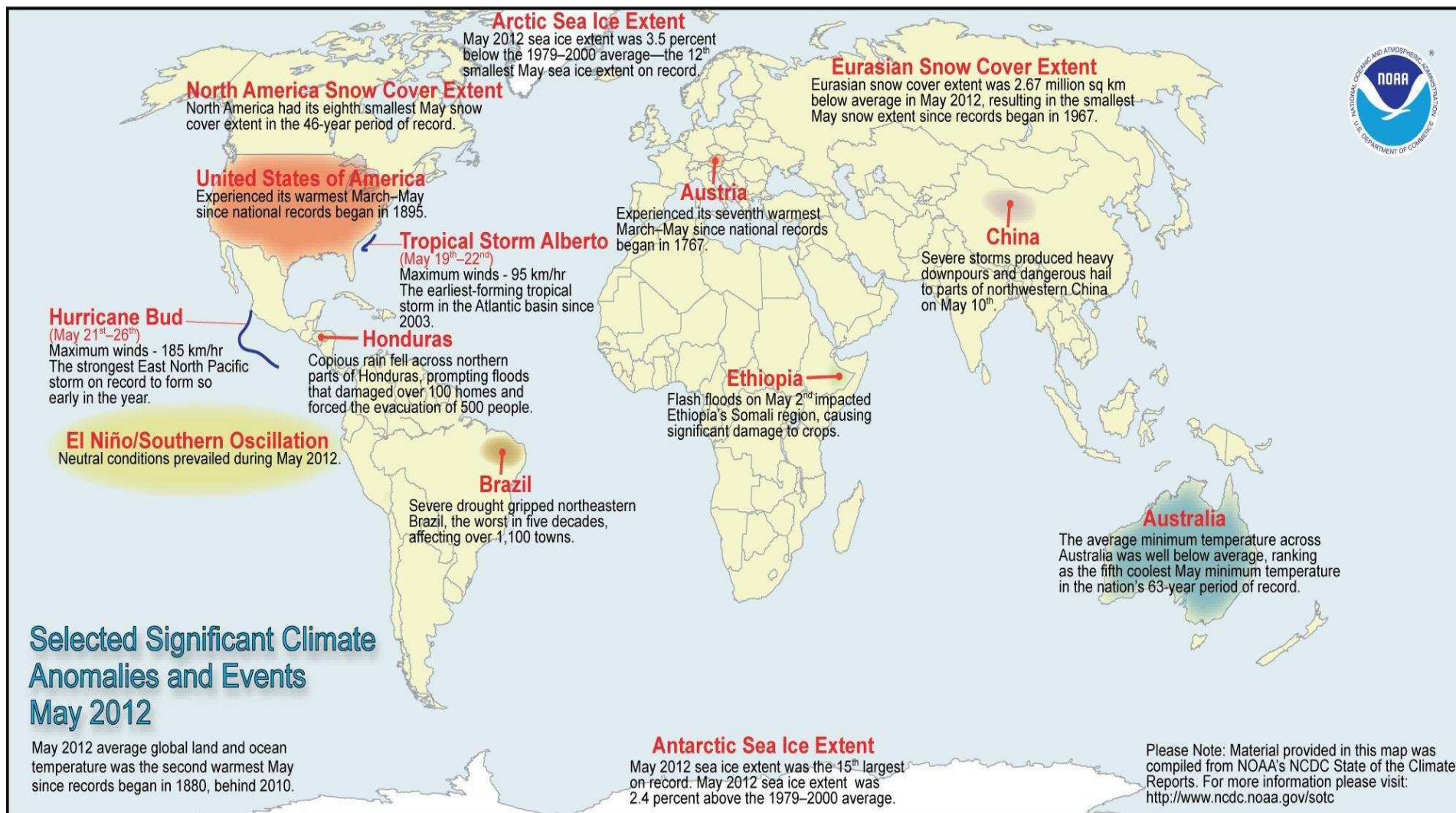


Figure 1: May 2012 selected climate anomalies and events maps NOAA Satellite and Information Service (2012)

Vast scientific suggestions, inevitable consequences including increase in sea-level, melting of the arctic region, global warming, increased natural disasters, unpredictable seasonal changes and the unnerving challenges faced by continuous global response in improving world policies, long-term sustainable research and technology, development and expansion of non-energy sources, corporate climate future and effective strategies, carbon pricing indicators and stable markets, knowledge transfer, adjustment and development to the realities of times ahead with the essential financial and technical support for developing countries without a doubt proves climate change to be one of the most significant challenges to the 21st century but ironically it is also the needed stimulating platform of opportunities to the world's low carbon and energy efficient transformation.

This challenge has led to series of international agreements, negotiations and governmental disputes and thus the birth of the United Nations Framework Convention on Climate Change (UNFCCC) at the Earth Summit in Rio de Janeiro, Brazil in 1992. The UNFCCC is the pioneering agreement on climate change upon which the foundation of the Kyoto Protocol treaty signed in Japan December, 1997 is laid **Whitehouse (2008)**. The Kyoto Protocol is the first global GHG emission reduction legal bind that sets targets for World Corporation on climate change abatement.

Advancement in the Kyoto Protocol Treaty has empowered a global interaction and response to the issues of climate change in developed countries (Annex 1) with 5% per year emission reduction targets from their 1990 emission levels between the year 2008-2012 (Annex B), transition economies and developing countries **Gao Pronove (2002)**. The 3 Kyoto Protocol treaty operations that give plasticity, encouragement to developed countries and participative direction to developing countries are **Gao Pronove (2002)**:

1. International emissions trading (ET) – transaction of emission permits also called Assigned Amount Units (AAU) amidst the industrialized countries..
2. Joint Implementation (JI) – emission offset crediting and tradable permits resulting from projects amidst industrialized countries often called Emission Reduction Units (ERUs).
3. Clean Development Mechanism (CDM) – emission offsets crediting resulting from projects in developing countries also called Certified Emission Reductions (CERs) Units.

This interaction has set a growing carbon market which is estimated to be worth US \$176 billion (€ 126 billion) with high level trading capacities of 10.3 billion tons of carbon dioxide equivalent (CO₂e) **World Bank (2012).**

1.2 CARBON CREDIT

Carbon credits are financial tradable incentives equal to one metric tonne of greenhouse gas (GHG) emissions based on carbon dioxide (CO₂) equivalent permanently removed or prevented from being emitted to the atmosphere. Carbon credits are also permits generated by any entity that has been official recognized by the UNFCCC and meet the Kyoto protocol initiative while having produced the technology to reduce, store or prevent significant measures of GHG pollutants from being emitted to the atmosphere.

Carbon credits can be produced in two types of market namely: the Compliance Market and the Voluntary Market. Carbon credits produced in the compliance market are achieved by projects approved by the UNFCCC and Kyoto Protocol including the Clean Development Mechanism (CDM) termed CERs in developing countries and the Joint Implementation (JI) termed ERUs in developed countries and the New South Wales Greenhouse Gas Abatement Certificate (NGAC) while carbon credits of the voluntary market are generated by certified independent international standards including Verified Carbon Standards (VCSs), Verified Emission Reduction (VERs) and Renewable Energy Certificate (REC) **Carbon Planet (2012).**

Carbon trading otherwise known as an emission trading scheme operates with the compliance and voluntary carbon credit by a transaction process of GHG carbon dioxide equivalent emission rights between developed, transitional and developing country.

In the compliance carbon credit trading market, Annex I countries inscribed in Annex B who have signed the Kyoto protocol to reduce their GHG emissions by at least 5% a year between 2008-2012 compared to their emissions in 1990, receive carbon credits from the United Nations equal to (usually less than their anticipated emission) the amount of GHG carbon equivalents targets set by the Kyoto Protocol for the countries. If a developed country is able to successful reduce its emission, the carbon credit received from the United Nations can be sold at a price depending on the availability and demand to other countries or country that

require these carbon credits to offset their emissions. Also, carbon credits can be earned and received from the United Nations, if a GHG carbon equivalent emitting facility or organisation of a developed country invests in a Clean Development Mechanism (CDM) project in a developing country with proven success of permanently prevented GHG emissions to the atmosphere **European environment agency (2011)**. Another aspect is the compliance carbon allowance trading market, which enables organisations or facilities in a country to sell carbon credits earned for successfully reducing its carbon emission below the emission target set by the country it operates (Cap and Trade) to other facilities within the same country that exceeds their emission targets thereby requiring these carbon emission allowances to offset their emissions **European environment agency (2011)**.

Offsets of carbon emission can also be used in the voluntary carbon market by individuals or organisations who are not directly offered emission targets by their country of operation but want to contribute significantly to carbon energy efficiency and climate change. Currently, several companies including British Petroleum (BP) help in calculating the carbon emissions by individuals and organisations and allocate voluntary carbon offsets which are removed from the carbon credit allocated to that country thereby making less carbon credits available for major carbon emitter in the country and ultimately restricting their carbon emission.

1.3 PRICING OF CARBON CREDITS

According to the basic principles of microeconomics on welfare economics, 'A consumer surplus is the amount of utility consumers derives above and beyond the price they pay for a good or service **Jon Gruber (2010)**. This also means a consumer willingness to pay the price for a good or service. In applying the consumer surplus to a supply and demand curve, the point of equilibrium identifies where the price is set equal to the willingness of the marginal consumer who at this point is indifferent to consuming or not consuming the good or service and achieving a zero consumer surplus as shown in Figure 2.

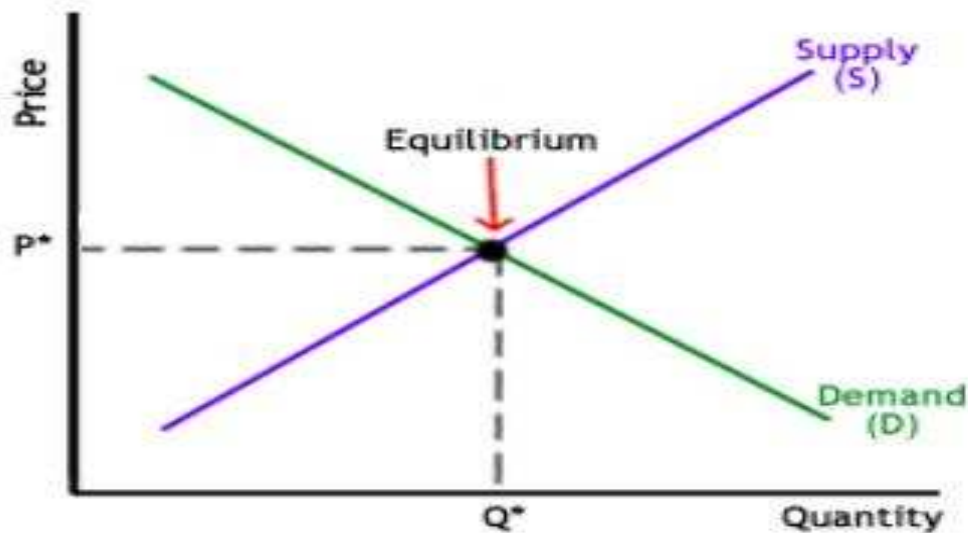


Figure 2: Demand and Supply curve Investopedia.com (2003)

Relating the above concept of the zero consumer surplus to the voluntary carbon market, the voluntary carbon credit at equilibrium that exists in a perfectly competitive market is the individual's willingness to pay equal to the set price of reducing his or her GHG carbon equivalent emission, but due to the challenges of attaining a perfect carbon market and fluctuating costs of voluntary carbon credits, an equilibrium may never occur and individuals or organisations may not be willing to pay because of the cost of the business.

1.4 CARBON MARKET WORTH

In 2011, an estimated worth US \$176 billion (£109 billion) or (€126 billion) with high level trading capacities of 10.3 billion tonnes of carbon dioxide equivalent (CO₂e) led by the European Union Allowances (EUAs) with 7.9 billion tonnes of CO₂e priced at US \$148 billion (£92 billion) or (€126 billion), increased secondary Kyoto offsets driven by liquidity in the CERs market and promising secondary ERUs market with 43% increase of 1.8 billion tons of CO₂e priced at US \$23 billion **World Bank (2012)**, the carbon market grew despite the economic recession sensitively propelled by a low carbon and efficiently green future economy. Though further analysis show good 63% increase occurring in the post-2012 CDM primary market largely by China and African countries contracted CERs, uncertainties surrounding the future of the carbon market reflect plunging of pre-2013 carbon prices in the AAU market by 49%, CERs by 32% to US \$1.0 billion (€0.7 billion) and ERUs by 36% as a result of the fast approaching end of the first Kyoto protocol pledge era in December 2012,

Canada's resignation from the Kyoto Protocol and developed countries now pushing for carbon reduction emission targets in transition economies at the recent 17th Conference of the Parties (COP) in Durban, South Africa in order to attain the world average temperature of 44(GtCO₂e) by 2020 **World Bank (2012)**.

The enormous challenges ahead require OPTIMIZING THE VALUE OF THE CARBON CREDIT because carbon trading still lies at the pivotal point of global response to climate change as it cuts across all continents and the world economy offering interaction and commitment of the entire world community and providing the needed time for extensive technological research including carbon capture and storage (which requires suitable storage formations that may not be applicable to all countries), renewable energy (wind turbines, sea wave power generation, solar, hydro power generation), nuclear power, biomass, energy efficiency and non-energy sources such as agricultural and afforestation.

1.5 OBJECTIVES OF THIS RESEARCH

1. Determine the GHG emissions produced from the electricity generated by countries on four continents.
2. Comparing the GHG emission carbon dioxide equivalent derived within the Kyoto Protocol commitment period of 2008-2012 and UNFCCC emission targets for developed and developing countries respectively to their 1990 emission baselines.
3. Analysis the effect of population on the world energy demand.
4. Optimize the voluntary carbon credit which is a major contributor to the enhancement and economics of a functional carbon trading market. This will be done by redesigning existing policies that will not only promote the carbon market but also act as a fierce move in reducing GHG emissions.

1.6 PERCIEVED BENEFITS

1. Increased participation in energy management and carbon efficiency to achieve a low carbon economy at a minimum cost.
2. Increased awareness of the voluntary credit market as the necessary booster to the carbon market.

3. Greater conscious emission reduction in urban cities of developed countries directly as a result of individual emission reduction.
4. Increased Cap and monitored Trade in developed countries leading to significant reduction in GHG carbon equivalents by the year 2020.
5. Great strides towards a low carbon, green efficient future.
6. Providing the needed time for extensive research in low carbon technologies including carbon capture and storage, renewable energy (wind turbines, sea wave power generation, solar, hydro power generation), nuclear power, biomass, energy efficiency and non-energy sources such as agricultural and afforestation.
7. Encouraged knowledge transfer, active participation and economic development in developing companies.

1.7 CONCERNS

1. With the end of the Kyoto Protocol first commitment era in December 2012, the compliance carbon market and its credit may no longer be in existence or be as valuable as it currently is.
2. The 'Trade' in the Cap and Trade system continues to allow major polluters of GHG carbon equivalent emit carbon as long as they remain under the emission targets of their operating countries and this does not strictly encourage emission reduction in their facilities.
3. Free carbon or emission allowances given to major industrial polluters under the Cap and Trade system continues to encourage more GHG carbon equivalent emissions, reduce carbon credit prices and increase energy cost as indicated in the European Union Trading Scheme **Kossoy & Guigon (2012)**.
4. Improper monitoring of actual carbon reduction schemes to ensure offsetting processes are justified.
5. The effect of carbon leakage. This involves major carbon emitting industries of Annex 1 countries transferring manufacturing processes that emit massive amounts of GHG to non-Annex 1 countries that are not committed by the Kyoto Protocol to a GHG emission target. This increases profit for the Annex 1 Company as a result of cheap labour and lower cost of production in developing countries or transitional economies but adversely affects the environment with steady increases of GHG

emissions in the atmosphere. A typical example is China, though seen as the emerging manufacturing destination; it has also become one of the most GHG emitting countries in the world.

1.8 DISSERTATION SUMMARY

Chapter 1 - the source of climate change, its effect and the resulting emergence of the Kyoto protocol. The compliance and voluntary carbon markets, their operations and the pricing of the carbon credits traded in these markets. The objectives, perceived benefits and concerns facing the carbon market are also highlighted. The need to optimize of the carbon credit is will definitely help to reduce carbon emissions and accelerate global participation towards a low carbon world.

Chapter 2 - The evolution of the climate change establishments is seen to have tremendously helped in reducing the amount of GHG emission in the atmosphere. The Kyoto Protocol which commits developed countries to reduce their emissions and also creates an active global participating environment but with its first phase ending in December 2012, uncertainties amongst the developed countries continue to increase and this is evident with the resignation of Canada backed by Japan and Germany, increased levels of emission in countries without reduction target, the huge financial demand on developed countries and has resulted in the failing of the Kyoto Protocol.

The relation between energy demand in the various national communication sectors and population also discussed shows that in most cases population may not be the driving force for increase in energy consumption.

Chapter 3 - The governing combustion equation showed that coal emitted more carbon dioxide emission than natural gas or oil. The methodology analysed three case studies with regards to the Annex I and Parties to the Annex I and the EIT countries. The electricity generated using the statistical world data compiled by British Petroleum in June 2012, was further analysed based on the emission factors of each country from 1990-2011 in order to determine the TCO_{2e} emitted by each country. The carbon credits were generated with respect to the assigned amounts issued by the United Nations and the CO_{2e} emissions from each country.

Chapter 4 - Amongst the Annex I and Parties to the Annex I, the Russian Federation's excess emission rights has encouraged its high electricity production and CO₂e emissions because it remains safe within its Kyoto Protocol emission limit. Japan and Germany also have experienced gradual reduction in emission levels.

The electricity generated per year for the 28 considered countries showed that the United States has the highest energy demand in the Annex I while China has the highest energy demand amongst the EIT countries. The latter is as a result of the economic boost in the leading EIT country.

The increasing rates of the TCO₂e and its effect on the populations show that the Annex I and Parties to the Annex I emit higher TCO₂e than the EIT countries even though their population is lesser.

The voluntary carbon market and its credits are also becoming the main focus in the generation of carbon credits for offsetting excess CO₂e emitted from Annex I and Parties to the Annex I.

Chapter 5 – The research was concluded based on the electricity generated and CO₂e emission results derived and the factors which would contribute to the optimization of the voluntary carbon market. The effects of the results were discussed and recommendations provided.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The effects of climate on the world has brought about the formation of different establishments that has increased the climate change awareness and helped governments in setting up effective climate policies. These establishments include: World Meteorological Organization (WMO), the Intergovernmental Panel on Climate Change (IPCC), the United Nations framework convention on climate change (UNFCCC) and the emission enforcing Kyoto Protocol. The carbon markets in the world will be examined to determine the action taken by individual countries to mitigate climate change at the lowest possible cost and in the most effective way. The relationship of energy and population and the major CO₂e emitting sectors will be explained.

2.2 THE EVOLUTION OF CLIMATE CHANGE ESTABLISHMENTS

The first world conference on climate change was led by the World Meteorological Organisation (WMO) at Geneva, Switzerland in the year 1979. It centred on the necessity to advance in scientific atmospheric processes with interests surrounding climate change, agriculture, water resources and energy **Jarraud (2009)**. Increasing threats to climate change by human- induced activities led to the formation of the Intergovernmental Panel on Climate Change (IPCC) in the year 1988 by WMO and the United Nations Environment Programme (UNEP). In 1992, the UNFCCC was adopted to encourage emission reduction in achieving stable GHG atmospheric concentrations and a world temperature of less than 2% within a period of time to allow ecosystems to naturally adapt to climate change and ultimately reduce its anthropogenic effect on climate change. To further commit industrialized and developing nations to their responsibilities in GHG emission reduction, the Kyoto Protocol was adopted on the 11th of December, 1999 and officially entered into force on the 16th of February, 2005. The Kyoto protocol is the legal bind of the UNFCCC that set emission targets for industrialized countries based on 5% per year emission reduction targets from their 1990 emission levels by 2008-2012 while supporting and monitoring transitional economies and developing countries active participation in climate change.

2.2.1 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

The IPCC was established in the year 1988 by WMO and the UNEP under the chairmanship of Professor Bert Bolin with the aim of reviewing, assessing and delivering current scientific and technical knowledge of climate change, its impact on the environment and socio-economic world sector and achievable response strategies. IPCC, also an intergovernmental

body supports governments of the United Nations member countries and scientists around the world to participate in its review process and plenary conferences to effectively understand the effects of climate change in different countries therefore ensuring the IPCC assessment reports are policy relevant **IPCC Working Group 1 (1990)**.

The definition of climate change by the IPCC is the state of change in climate properties either by natural variability or as a result of human activity recognized using statistical test, datasets and analysis which perseveres over an extensively long (decades) period of time **IPCC (2007)**.

2.2.1.1 IPCC First Assessment Report (FAR)

The first assessment report (FAR) of the IPCC produced in August 1990 by three Working Groups. Working Group I developed four scenarios including a clearly centred business-as-usual approach in the first scenario with a global mean temperature of 0.3°C and an assumed progressive increased level of controls with global mean temperatures (GMT) 0.2°C, > 0.1°C and 0.1°C in the second, third and fourth scenarios respectively on the effect of GHG on the earth temperature and its rising effect due to anthropogenic sources **IPCC Working Group 1 (1990)**. The summary of the three scenarios indicated that over the last 100 years, the mean world's surface air temperature had increased by 0.3°C to 0.6°C with warmest years being in the 1980 and over these time, global sea levels has increased by 10-20cm. Further concerns over inconsistency of data on climate change issues were prominent in the first assessment report. These assumptions and concerns formed the negotiation of the UNFCCC **IPCC Working Group 1 (1990)**.

The Working Group II was based on the existing outcome of scenarios developed by the Working Group 1. The impacts of climate change on agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, human health and settlements including the air quality, changes in ultraviolet- radiation, energy, transportation and industrialization effects, ocean and costal zones and lastly seasonal snow covers, ice and permafrost. The results of the Working Group II in the face of estimated changes to climate highlights the inadequate provision of knowledge on climate change especially at the regional stage and the resulting consequence of climate change on the world's increasing population **Tegart et al (1990)**.

The Working Group III response strategies centred on the scenarios and impacts identified by Working Groups I and II analysis the flexible and progressive approach required by nations in their attempt to reduce or limit GHG emissions. The projected increase in world population was also stressed as a major factor of GHG emission increases. The progressive approach considered short term, long term and adaptation measures including improved forest management, increased efficient use of natural resources as carbon sinks, develop new technologies and utilize cleaner sources of energy. Government commitments to setting targets for CO₂ and other GHG emissions were emphasized **Bernthal *et al* (1990)**.

2.2.1.2 IPCC Second Assessment Report (SAR)

The IPCC second assessment report (SAR) completed in 1995 was based on the objective of the UNFCCC. It concentrated on three distinct but interrelated choices of the UNFCCC which centred on assessing scientific and technical information relevant to GHG emissions stabilization levels, net emissions pathway and mitigation technologies and policies of climate change **IPCC (1995)**.

The IPCC Working Group I of SAR contributed to the findings of the IPCC FAR and emphasized on the increasing abundance of GHG in the atmosphere, suggesting that an extensively large amount of emission cuts would be required to attain the ultimate goal of the UNFCCC. SAR also acknowledged progress in simulating climate models particularly with the inclusion of radiative forcing agents in the form of sulphate aerosols and stratospheric ozone and utilized this simulative aptitude to compare the perceived patterns of regional temperature changes. The report concluded that though quantifying human influences on climate change was limited, balance of evidences suggest the effect was distinct **Albritton *et al* (n.d)**.

The IPCC Working Group II of SAR charged with reviewing the current knowledge on impacts of climate change affecting the physical and ecological systems, human health and socio economic sectors coordinated its activities with IPCC FAR Working Groups I and II to provide scientific, technical and economic information on potential adaptation and mitigation strategies. With the aim of achieving the objective of the UNFCCC, vulnerability analysis was carried on different economies and institutional issues in developing and developed countries to recognize the pressure on population demographics, land-use practise,

industrialization, energy consumption patterns, air and water pollution and soil degradation **Watson *et al* (1995)**.

The frameworks of the IPCC working Group III focused on mitigation policies and socio-economic assessment of cost benefit analysis, incorporation of equity and social considerations, intergenerational equity matters, GHG limitation and enhancement of natural carbon sinks. Further recommendations on research advancement of economic understanding of non-linearities, new technologies on economic growth, sustainable consumption and energy efficiency of non-fossil fuel options in energy generation were made **Bruce *et al* (1995)**.

2.2.1.3 Summary of The IPCC third Assessment Report (TAR) and Fourth Assessment Report (AR4)

The third assessment report (TAR) released in May 2001 contained confirmation the findings from SAR, provided new solid evidence on global warming, decided to amend the list of Annex II countries to the UNFCCC and adopted an initial guidance to an entity entrusted with the financial mechanism of the convention funding including organized and implemented national adaptation programmes of actions (NAPAs) for least developing countries **United Nations (2002)**.

The fourth assessment report (AR4) compiled by the three working groups of the IPCC was finalized and adopted in May 2007. It concentrated on the unequivocal effects of climate change occurring and its continuous effect due to delay in urgent actions to achieve low emission levels of existing and new greenhouse gases. It also discussed issues on long term mitigation mediums and means of adaptation to climate change in all countries especially in developing countries for sustainable development **IPCC (2007)**.

Figure 3 shows the clockwise linkage in deriving climate changes and impact from socio-economic information and emission and counter clockwise linkages that assess possible sustainable development paths and global emission restrictions to be avoided.

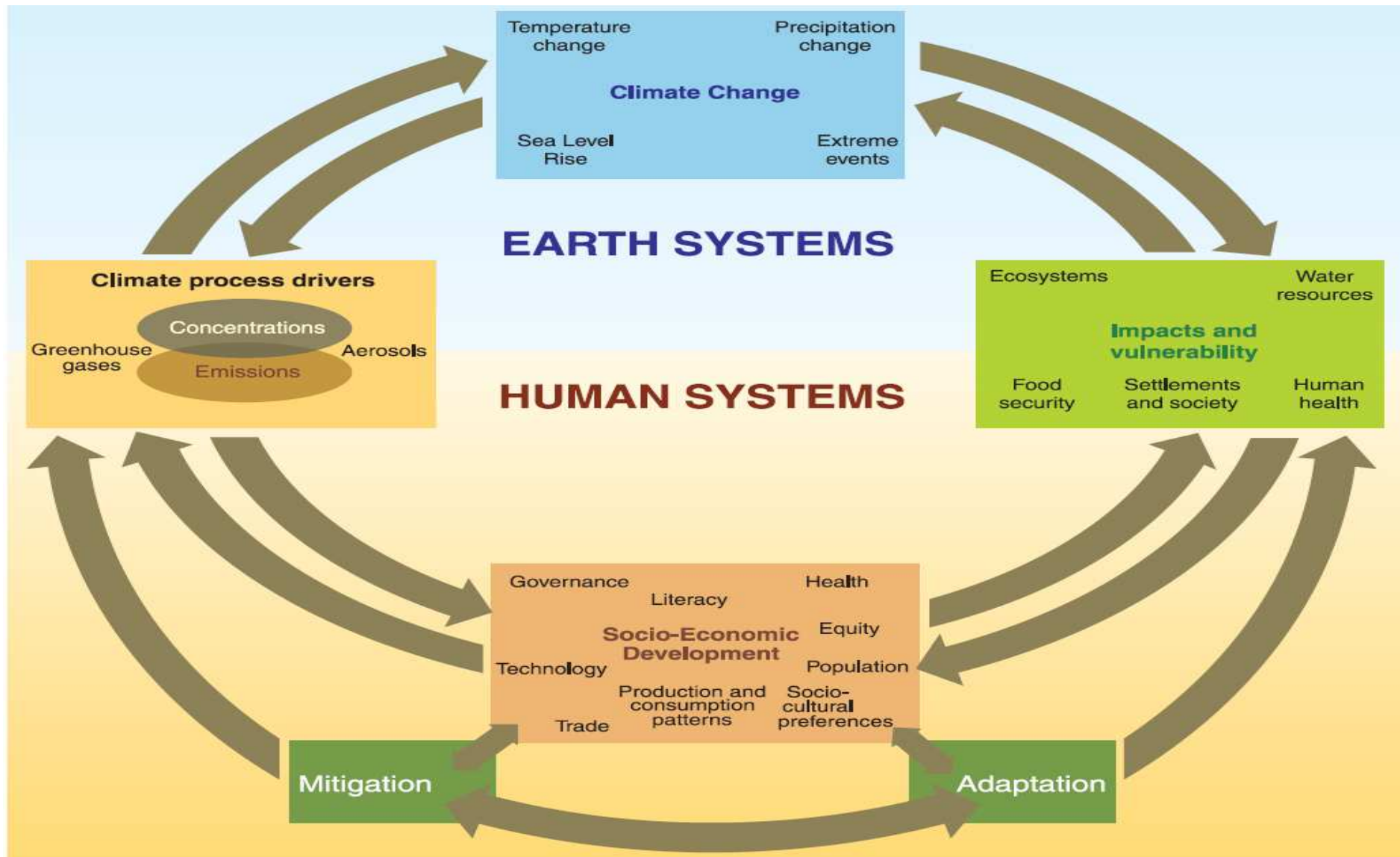


Figure 3: Schematic framework of anthropogenic climate change drivers, impact and responses IPCC (2007)

2.2.2 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and open for signatures by States Members of the United Nations or of any of its specialized agencies or that are Parties to the Statute of the International Court of Justice and by regional economic integration organizations, at Rio de Janeiro in 1992 during the United Nations Conference on Environment and Development until the 19th of June 1993 at United Nations Headquarters in New York. The UNFCCC signatories, ratification and entry into force of United Nations member countries date are shown in Table 11 refer Appendix A **UNFCCC (2012)**.

The UNFCCC officially entered into force in March, 1994 and currently accounts for a membership of one hundred and ninety-five (195) countries of which one hundred and sixty-five were ratified (165) commonly known as Conference of Parties (COP). With an ultimate objective in stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system within a timeframe sufficient to allow ecosystems to adapt naturally to climate change and ensuring that food production is not threatened enabling economic development to progress in a sustainable manner, the UNFCCC acknowledges the global nature of climate change and seeks the cooperation and effective participation of all countries **United Nations (1992)**.

The principle actions employed by the UNFCCC in achieving the above objective are as follows:

1. Ratified countries of the UNFCCC have the responsibility to reduce GHG emissions which result in adverse effects of climate change for the gain of the present and future generation of humanity on the basis of equity and according to a common but differentiated responsibility with developed countries (Annex 1) taking the lead.
2. Industrialized countries under the convention are to support developing countries by providing financial support and share technologies in order to mitigate and adapt to climate change.
3. All ratified countries are to work to reduce climate change due to anthropogenic sources to achieve sustainable development.

4. Supportive cooperation of all COP to promote an open economic system leading to sustainable economic growth and development in all countries **United Nations (1992)**.

2.2.3 KYOTO PROTOCOL

The Kyoto Protocol, the legal bind of the UNFCCC was adopted on the 11th of December 1997 in Kyoto, Japan and entered into force on the 16th of February 2005. The implementation of the rules and regulations governing the Kyoto Protocol was adopted in 2001 and called Marrakesh Accords **United Nations (1998)**.

The Protocol is committed to world cooperation in reducing global GHG emissions which results in climate change by setting targets of 5% per year emission reduction for developed countries from their 1990 baseline emission levels between 2008-2012 Kyoto commitment period, unless as otherwise stated in Article 3 of the United Nations ‘Any other Party included in Annex I undergoing the process of transition to a market economy which has not yet submitted its first national communication under Article 12 (cited in United Nations, 1992) of the Convention may also notify the Conference of the Parties serving as the meeting of the Parties to this Protocol that it intends to use an historical base year or period other than 1990 for the implementation of its commitments under this Article. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall decide on the acceptance of such notification’ **United Nations (1998)**. The Annex 1 countries to the UNFCCC are called Annex B parties or countries when they ratify the Kyoto Protocol.

The Annex B emission targets and parties emissions of GHG in the base year determine the parties initial assigned amount for the Kyoto Protocol first five-year commitment period from (2008-2012). The quantity of the initial assigned amount is denominated in units called Assigned Amounts Units (AAUs). An AAU represents an allowance to emit one metric tonne of carbon dioxide equivalent (TCO₂e) **UNFCCC (2008)**. In accordance with Decision 13/CMP.1 which was adopted by the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, held in Montreal, Canada in December 2005, Paragraph 6 of the Annex to Decision 13/CMP.1 states that: ‘each Party included in Annex I shall facilitate the calculation of its assigned amount pursuant to Article 3, paragraphs 7 and 8, for the commitment period and demonstrate its capacity to account for its emissions and assigned amount. To this end, each Party shall submit a report, in two parts, containing the

information specified in paragraphs 7 and 8 below’ UNFCCC (2006). The Decision 13/CMP.1 states that ‘each Party included in Annex I with a commitment inscribed in Annex B shall submit to the secretariat, prior to 1 January 2007 or one year after the entry into force of the Kyoto Protocol for that Party, whichever is later, the report referred to in paragraph 6 of the annex to the present decision’ UNFCCC (2006).

2.2.3.1 Kyoto Protocol Market Mechanisms.

As highlighted in section 1.1, the Kyoto Protocol empowers an effective global participation between developing and developed countries by 3 market mechanisms or treaty operations including:

1. International Emissions Trading (ET) or The Carbon Market
2. Joint implementation (JI)
3. Clean Development Mechanism (CDM)

2.2.3.1.1 International Emissions Trading or the Carbon Market

The emission trading or carbon market operates a trading system of Assigned Amount Units (AAUs) of emission permits issued by the United Nations, between industrialized countries with emission target commitment under the Kyoto Protocol (Annex B Parties) for a commitment period from 2008-2012 . Annex B parties who have been able to successfully reduce their GHG emissions below their required Kyoto Protocol target can sell their excess or ‘un-used’ AAUs to countries that go over their target UNFCCC (2012).

The AAUs are tradable carbon credits which equal one metric tonne of greenhouse gas (GHG) emissions based on their carbon dioxide (CO₂) equivalent permanently removed or prevented from being emitted to the atmosphere. Another tradable carbon credit unit is the removal unit (RMU) which is used on the basis of land use, land-use change and forestry (LULUCF) for afforestation and reforestation activities that reduce GHG emission to the atmosphere UNFCCC (2012).

2.2.3.1.2 Joint Implementation (JI)

The JI allows Annex B parties or countries to earn emission reduction units (ERUs) from an emission reduction or removal project in another Annex B country or countries. The ERUs are also tradable carbon credits. The host Annex B country benefits from technology transfer and development JI (2012). For a country to host a JI project, qualifying procedures known

as Track 1 and Track 2 are used to ascertain the eligibility of the host country as stated in the JI guidelines. Track 1 procedure are for countries who have met the eligibility requirements as stated in Article 6, paragraph 23 of the JI guidelines while Track 2 procedure are for countries who have not met the eligibility requirements as stated in Article 6, paragraph 24 of the JI guidelines **UNFCCC (2006)**.

In November 2010 at Cancun, Mexico, the sixteenth session of the Conference of Parties to the UNFCCC and the sixth session of the COP serving as the Meeting of Parties (CMP) to the Kyoto Protocol clarified certain JI guidelines including:

1. Annex 1 countries to the Convention in the process of complete ratification of the Kyoto Protocol but not yet been engraved as Annex B parties and who wishes to host JI projects.
2. Continuous issuance and transfer of ERUs by the host country of a JI project.
3. Commitment to a maximum temperature increase of 2°C above pre-industrial levels and the lowering of this maximum temperature to 1.5°C in future.
4. Establishment of a Green Climate Fund and Cancun Adaptation Framework for project financing and stronger climate change actions in developing countries **UNFCCC (2010)**.

2.2.3.1.3 Clean Development Mechanism (CDM)

The CDM boosts emission reduction projects in developing countries and through these projects certified emission reduction (CER) carbon credits are earned and traded. Industrialized or developed countries who invest in CDM project in developing countries acquire the CERs generated as a result of the reduction or permanent removal of GHG emission from the atmosphere in order to offset or which counts towards their Kyoto Protocol emission commitment. The CDM stimulates sustainable development, technology transfer, employment opportunities and climate change awareness in developing countries. The CDM is also the main source of the UNFCCC adaptation fund which is financed by 2% duty on CERs issued by the CDM **UNFCCC (2012)**.

According to the **UNFCCC (2012)**, the CDM recently recorded over one (1) billion tonnes of CO₂ equivalent mitigated since the year 2004. The sum up to this amount is an aggregate of the following successes:

1. In Colombia, 180 million passenger cars were removed from the road per year which equals 4 tonnes of CO₂ equivalent per second or 2.5 million tonnes of CO₂ equivalent offsets per week.
2. 4600 CDM projects have been registered which includes 1900 small scale projects and 3200 renewable energy projects; an example is shown in Figure 4.
3. A total of 161 countries are now involved in CDM with 76 of these registered and CERs currently issued to projects in 50 countries.
4. Over 215 billion US Dollars have been invested in CDM projects in developing countries.
5. More than 4500 organizations are involved in CDM and over 2500 experts have been trained by the UNFCCC.



Figure 4: CO₂ solutions CDM project: Eurus wind farm UNFCCC (2012)

The CDM is a market oriented mechanism and therefore most CDM projects are mostly concentrated in China, Brazil, India, Mexico and South Africa. The reason for this is that though there are other developing countries, industrialized countries that finance these CDM projects look to invest in countries where there are little to none security risks, strong financial systems for return on investment in a short period of time, qualified labour, reduced project cost, sound investment environment and most importantly where the potential to reduce GHG emissions is high. Some host countries of CDM projects are highlighted in the Table 11 refer Appendix A.

2.3 WORLD ECONOMIES

The world economies are grouped into three categories namely:

1. The G8: world leading industrialized economies which includes the United States of America, Great Britain, France, Germany, Canada, Italy, Japan and Russia.
2. The G20: the emerging transitional leading economies and regional capitals representing 90% of the global economy comprise of Argentina, Australia, Brazil, China, Turkey, Indonesia, India, South Africa, Saudi Arabia, Mexico, South Korea and the European Union **Recknagel (2010)**.
3. The remaining developing countries.

According to the **UNFCCC (2012)**, the world economies or parties are divided into three main groups based on their membership of the Organisation for Economic Co-operation and Development (OECD), the Economies in Transition (EIT parties) and according to their different emission commitments.

In 1960, twenty countries signed the Convention on the OCED which was officially inaugurated on 30th September 1961. It presently consists of 34 countries with the sole aims of achieving the highest sustainability standards of economic growth and development, contributing to great economic expansion in member and non- member countries in the process of economic development and great expansion of world trade on a multilateral, non-discriminatory basis in line with international legislation **OECD_a (n.d.)**. The list of these countries is given in Table 1.

Table 1: List of OECD member countries OECD_a (n.d.)

Countries	Ratification Dates of the Convection
Australia	7 June 1971
Austria	29 September 1961
Belgium	13 September 1961
Canada	10 April 1961
Chile	7 May 2010
Czech Republic	21 December 1995
Demark	30 May 1961
Estonia	9 December 2010

Finland	28 January 1969
France	7 August 1961
Germany	27 September 1961
Greece	27 September 1961
Hungary	7 May 1996
Iceland	5 June 1961
Ireland	17 August 1961
Israel	7 September 2010
Italy	29 March 1962
Japan	28 April 1964
Korea	12 December 1996
Luxembourg	7 December 1961
Mexico	18 May 1994
Netherlands	13 November 1961
New Zealand	29 May 1973
Norway	4 July 1961
Poland	22 November 1996
Portugal	4 August 1961
Slovak Republic	14 December 2000
Slovenia	21 July 2010
Spain	3 August 1961
Sweden	28 September 1961
Switzerland	28 September 1961
Turkey	2 August 1961
United Kingdom	2 May 1961
United States of America	12 April 1961

The EIT countries are parties in the process of transition to a market economy under the UNFCCC. The European EIT Countries now included as Parties to the Annex I are: Belarus, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Romania, Russian Federation, Slovenia and Ukraine **OECD_b (n.d)**.

In line with the **UNFCCC (2012)**, the three main groups of the world economies include:

1. Annex I Parties: These include industrialized countries that were members of the Organisation for Economic Co-operation and Development (OECD) in 1992 and economic in transition countries (EIT parties), Russian Federation, the Baltic States and certain Central and Eastern European States.
2. Annex II Parties: These include OCED members of Annex I only who are required by the Convention to provide financial support and technology transfer for developing countries on activities relating to climate change and its abatement.
3. Non - Annex I Parties: These include most developing countries with certain groups most vulnerable to the impacts of climate change.

2.4 CARBON TRADING MARKETS

2.4.1 THE EUROPEAN UNION TRADING

The European Union Emission Trading Scheme (EU ETS) originally a regional carbon market of the European Union's (EU) political economy with the main interest to promote GHG reductions in a cost effective, economical and efficient manner to drive the EU decarbonisation has developed into the most successful carbon market with estimates of about 80% of the global carbon market **Egenhofer (2011)**.

The EU ETS has experienced growth despite the annual average decline of the European Union Allocation (EUA) carbon price by 4% year on year (yoy) to £11.6/tonnes (US\$18.8/ton) and a combined declined in CERs and ERUs by 21% yoy to £7.9/tonnes (US\$12.8/ton) as a result of over- allocation or over supply of EUA's. Further setbacks to the decline in the EUA carbon price value was as a result of drastic reduction in EU emissions during the 2008-2009 economic recession followed by a weak industrial restoration, the current supply of international carbon offsets largely by the EU ETS **Kosoy & Guigon (2012)**. The EU ETS generates European Union Allocations (EUA's) which are carbon credits representing the right to emit one tonne of GHG emissions.

Figure 5 show the decline of trading volumes and carbon prices for EUA's, CER's and ERU's in the EU ETS secondary market from 2008-2011.

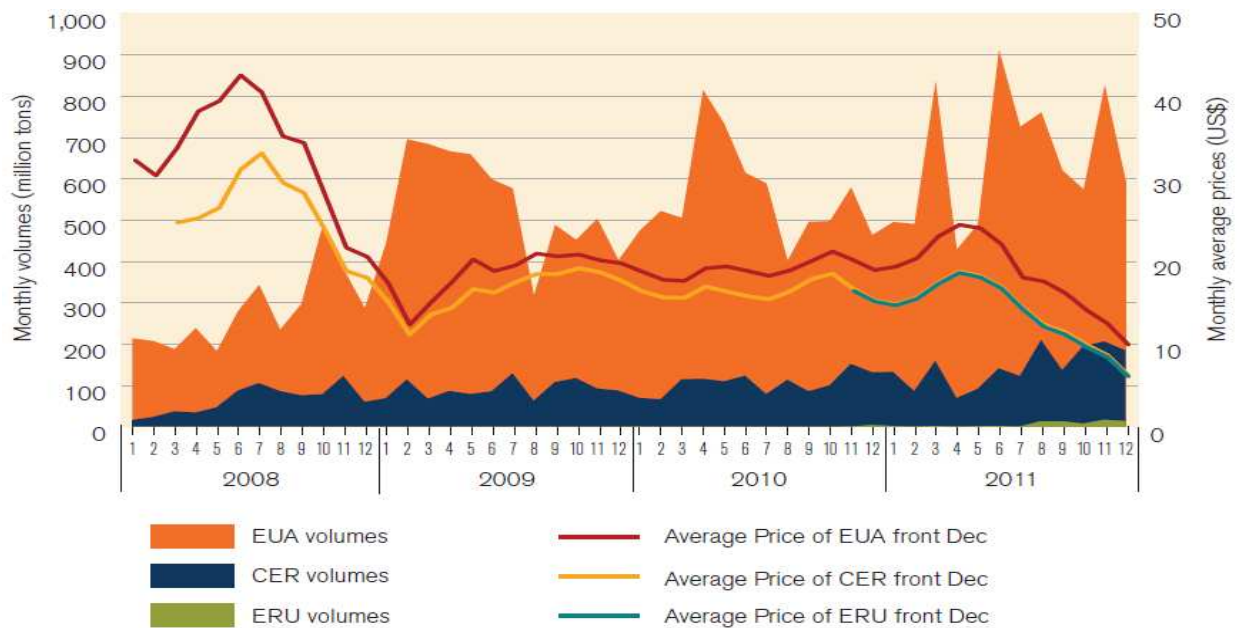


Figure 5: Decline of trading volumes and prices for EUA's, CER's and ERU's in the EU ETS secondary market from 2008-2011 Kossoy & Guigon (2012).

A new European Trading Scheme (ETS) as proposed by the European Union in 2012 addressed the changes in the EU ETS which includes:

1. A new ETS with a single EU-wide cap (national carbon emission target) that will decrease annually with linearity by 1.74% starting in 2013 and beyond 2020.
2. From 2013, power companies will buy their EUA at auctions with the exception of a few member states with the option to postpone the full auctioning process temporarily while other sectors free allocation will be progressively phased out starting at 80% in 2013, decreasing to 30% in 2020 and finally to 0% at 2027 **Kossoy & Guigon (2012)**.
3. The ETS will also extend to the aviation, chemicals and aluminium and other sources of GHG emissions **Egenhofer (2011)**.

2.4.2 CHINA'S CARBON MARKET

China's remarkable economic growth in 2010 as the second largest economy in the world took an overwhelming effect on its primary energy consumption and domestic supply leading to environmental and social challenges including being the world's largest GHG emitter in 2008 **Kossoy & Guigon (2012)**. To this effect, the Chinese government set up the Eleventh

Five-Year Plan (2005-2010) and the Twelfth Five Year Plan (2011-2015) to extensively address energy conservation and emissions reductions.

China's Eleventh Five-year plan utilized climate change mitigation as a vital opportunity in economic development and structure transformation. Mandatory requirements and administrative approaches to energy conservation and GHG emission reductions were acknowledged and implemented with the assistance of the Chinese government financial subsidies in eliminating outdated forms of production, shut-down of inefficient power plants, steel factories and cement factories resulting in a significant decline in China's primary energy consumption per unit GDP by 19.1% with 630 million tonnes of standard coal saved. This led to a total reduction in GHG emissions by about 1.5 billion tonnes of CO₂e **Lin et al (2011)**.

China's crucial point in industrialization and improving the living standard of the Chinese people require powerful policies on sustainable development and in November 2009, the Chinese government set targets for climate change which increased from 20% in the eleventh five-year plan to between (40-45)% with a baseline in 2005, 15% utilization of renewable energy for primary energy consumption **Lin et al (2011)** and increase of forest carbon sinks by an additional 14.3 billion cubic meters **Kossoy & Guigon (2012)**. These targets were formally approved for the twelfth five-year plan in March 2011 by the National People's Congress of China to effectively monitor, measure, report and verify GHG emissions and set up a trading market for carbon credit starting with a domestic voluntary carbon market.

The China's domestic market as proposed by the central government would include:

1. Standardization of the voluntary markets by introducing basic registration systems, defining trading sites, products and clarification on the new validation, verification and carbon credit issuance methods **Kossoy & Guigon (2012)**. In 2009, the Panda Standard was launched to help develop china's national capacity in domestic trading and promoting Agriculture, Forestry and Other Land Use (AFOLU) GHG offset project. The China Green Carbon fund (CGCF) was launched in July, 2010 to mitigate GHG emissions by encouraging carbon credit trading, bio-technology and carbon sinks **Lin et al (2011)**.
2. The National Development and Reform Commission's (NDRC's) construction of regional pilot projects on carbon policies in five provinces and eight cities namely: Guangdong, Hubei, Liaoning, Shaanxi and Yunnan as well as Tianjin, Chongqing,

Hangzhou, Xiamen, Shenzhen, Guiyang, Nanchang and Baoding **Lin et al (2011)** to actively explore low-carbon development technologies and a green lifestyle.

Figure 6 further elaborates the steps, policies and governance and technical support of the twelfth five-year plan in building a carbon trading market.

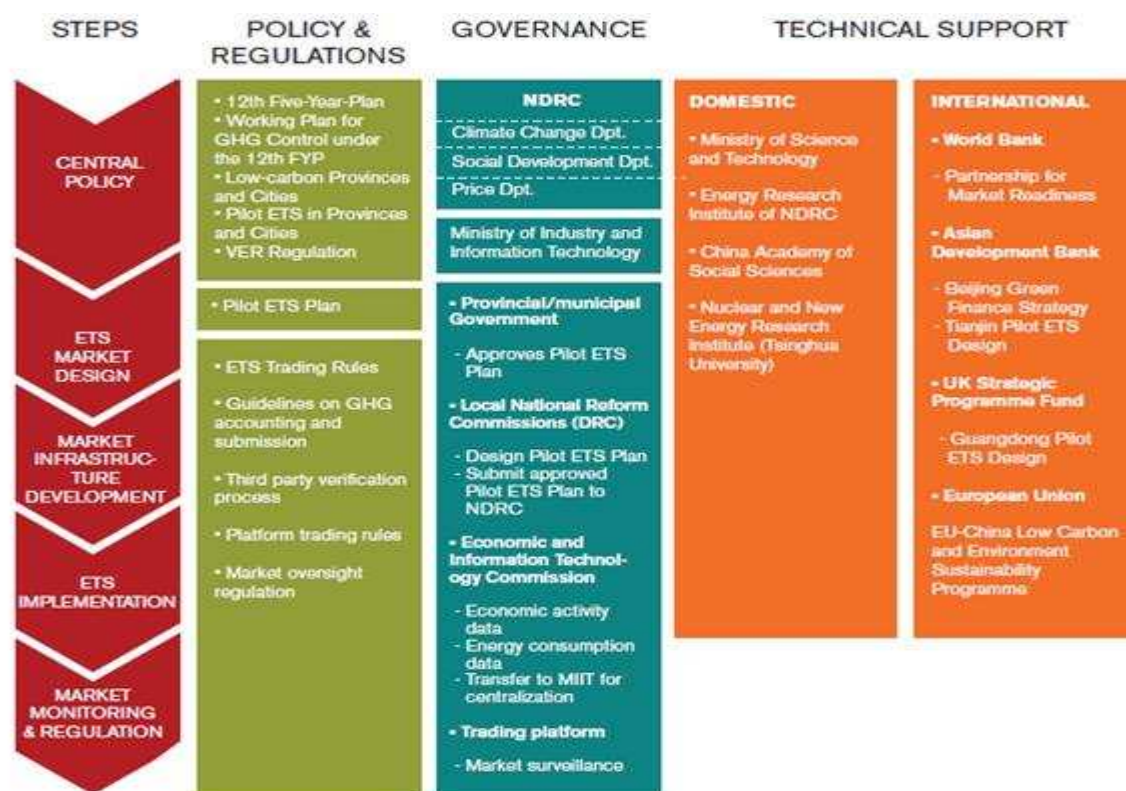


Figure 6: China's process in building a carbon trading market (Kosoy & Guigon (2012)).

2.4.3 THE UNITED STATES OF AMERICA NATIONAL CONTEXT POLICIES FOR GLOBAL PROBLEMS

The constant reluctance of the United States of America to ratify the Kyoto Protocol has led to formation of its internal 'Cap and Trade'. The national carbon – pricing policy has been highly favoured by economist because they feel that there is no other better approach to meaningfully reduced emission at a least cost and also the national carbon pricing provides strong incentives that motivate the control of national CO₂ emissions in all industries lading ultimately to a switch to eco- friendly technology. In 2009, the U.S. Supreme Court and the Obama's administration subsequent endangered findings suggest GHG are harmful to public health and welfare. This resulted in the Clean Air Act **Stavins (2011)**.

The United States federal climate policy interactions with subnational policies can be seen problematic, benign or positive as a result of its scope and stringency **Stavins (2011)**. The interactions are highlighted as follows:

1. Problematic interactions: The United States of America has observed that the ‘green states’ which have more stringent policies than the federal policy aids to reduce the pressure of emission reduction on other states thereby leading to mission increases, 100% emission leakages, no progressive environmental gain from the ‘green states’ added activities and a national loss of cost effectiveness. An example is AB 32 combined with Waxman-Markley/H.R. 2454 **Stavins (2011)**.
2. Benign Interactions: this occurs where the state policies are less stringent than the federal policies therefore rendering the state policies irrelevant.
3. Positive Interactions: This interaction occurs in a case where the states create pressure for more stringent federal policies, continuous free flow of information is made between state, regional and federal authorities in policy formation, and energy efficient investment in renter-occupied properties **Stavins (2011)**.

Internationally, The United States of America can link with trading systems by forming a carbon linkage operating between Two ‘Cap and Trade’ systems or a ‘Cap and Trade’ and an emission reduction credit system. In the credit system, the entities only benefit from the opportunity to sell credits as they are not required to meet emission targets **Stavins (2011)**.

Stavins Roberts (2011) suggests that a partial solution to these problems would occur if primary policies engaged in the state and regional levels is ‘Cap and Trade’ with an ultimate linkage to the respective carbon market.

2.5 WHY THE KYOTO PROTOCOL IS FAILING

From the above discussion, it is evident that the carbon trading market of the Kyoto Protocol is failing as a result of the following:

1. Plummeting carbon credit prices, uncertainty as a result of the end Kyoto Protocol first commitment era in December 2012 and the coming on stream of the enforceable agreement to control all nations’ emission by 2020.
2. The withdrawal and reduced commitment of the G8 world economies as reflected in the recent resignation of Canada from the Kyoto Protocol with supporting countries

including Japan and Russia and the firm reluctance of the United States of America to ratify the protocol at the recent Durban Climate change conference in 2011 further increased the uncertainty in effectiveness of the compliance market.

3. The fragmented climate change policies resulting from pioneering Kyoto Protocol ratified countries struggling to maintain their economies will eventually lead to increase in mitigation costs, unstable carbon prices as highlighted in section 2.3.1 as a result of EUA full auctions from 2013 and reduced action on GHG emission reduction as proposed in their Kyoto commitment.

With the uncertainty surrounding the Kyoto Protocol and the compliance market that operates based on the emission targets of the Annex B countries, it is likely that the future of the carbon market will also be guided by the voluntary sector by virtue of the fact that the voluntary carbon market preceded and guided the establishment of the compliance carbon market, and given the host of voluntary standard knowledge now utilised by the compliance market.

2.6 ENERGY AND POPULATION

The significance of the size and growth of world population on the demand of energy may be on the increase in a context or on the decrease in another context. The industrialization era in the 1950's led to an up thrust of energy consumption in the world with the springing up of manufacturing industries and infrastructures to boost productivity and economic growth. Further in this path, the growing population desiring a more comfortable lifestyle chose options that increased energy usage.

With the issues concerning the declining of the world's fossil fuel for years, governments now more than ever look for ways to become more energy efficient by investing in renewable energy and conservative energy management options. The decarbonisation structures being put in place in major world economies with the aim of achieving zero carbon at the long run would definitely reflect on a decrease in energy consumption even with a continued increase in population.

Figure 7 shows the world energy, GDP and population relation from 1965 to 2003 **WEAP (2007)**. This supports the overall increase in population resulting in an increase in energy supply.

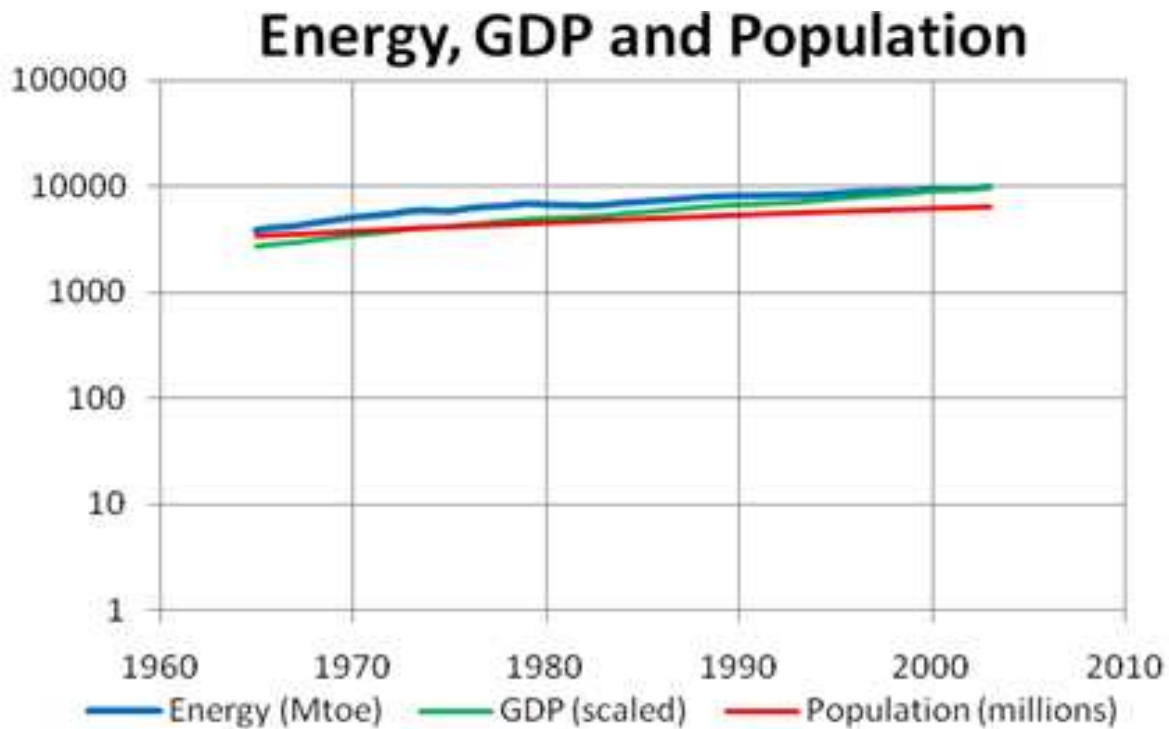


Figure 7: World energy, GDP and Population WEAP (2007)

Though the above paragraph can be said to be true for the developed world, the developing countries that have limited access to constant energy consumption but with constant population increase can be seen as energy – population decreasing linkage.

According to **Darmstadter (2004)**, the average per capita GDP (Gross Domestic product or Income) and energy consumption of the world's developing countries are, respectively, only about one-seventh and one-eighth those of industrial areas. Notwithstanding this marked per capita disparity, given the sheer population size of developing regions—over three-quarters of the world total—the absolute amount of energy consumption and of GDP are relatively large: one-third of world energy use and about two-fifths of world GD.

Figure 8 shows the effect of world population with declining energy **WEAP (2007)**.

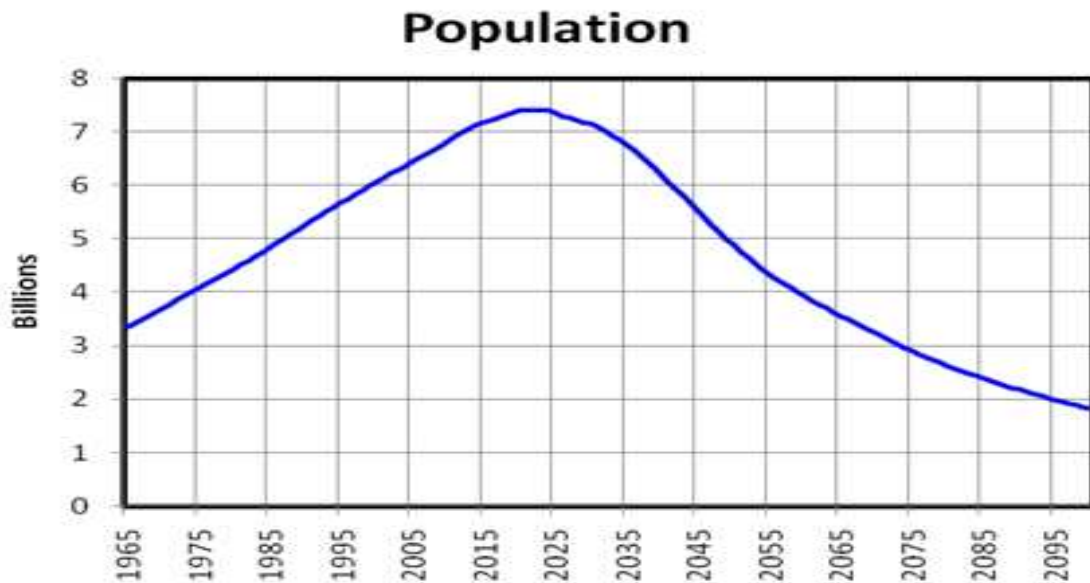


Figure 8: World population with declining energy WEAP (2007)

The national communication sectors for GHG carbon dioxide emissions include electricity and heat, transportation (air, water, and land), manufacturing industries, process industries and many more. Of these sectors, electricity and heat and transportation produces nearly two-third of the global CO₂ emissions. The World Resource Institute (2005) shows the breakdown of GHG emissions production by sector, end-use/activity reflected in Figure 9.

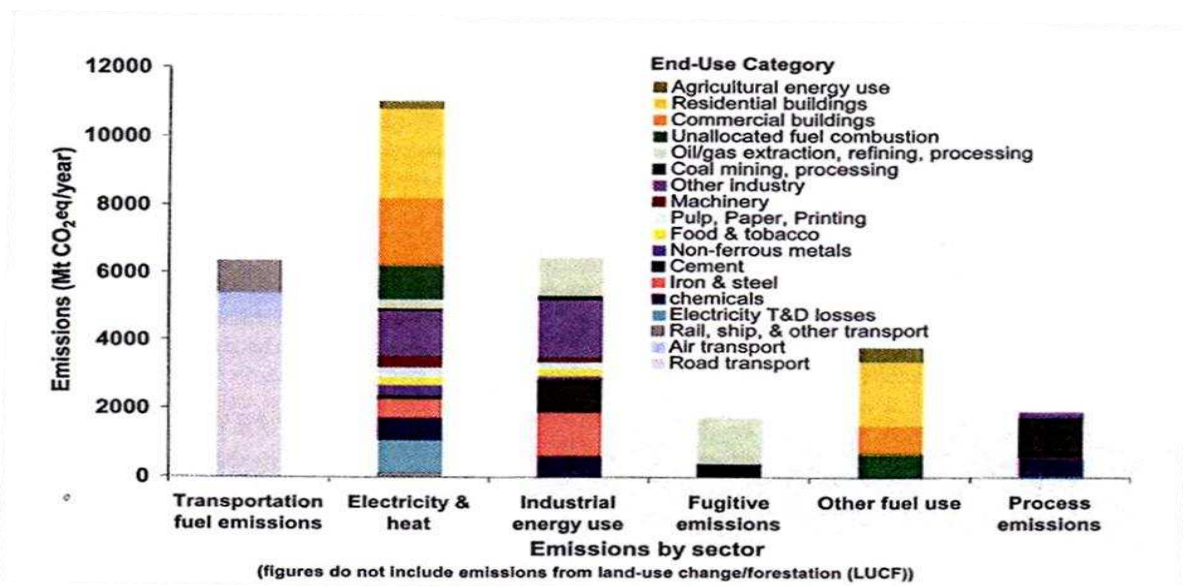


Figure 9: The breakdown of GHG emissions production by sector, end-use/activity World Resource Institute (2005).

In 2009, electricity and heat was the largest producer of CO₂ emissions accounting for 41% of the world's total emissions as a result of the increased demand and utilizing of the highest carbon emitting fossil fuel, coal **IEA (2011)**. Based on this result it was reported by International Energy Agency (IEA), that the United States of America, China and India generated about 18%, 20% and 5% of the world's CO₂ emissions while accounting for 5%, 20% and 17% of the total world's population respectively. This shows that industrialized countries emit higher amounts of CO₂ per capita than the rest of the world; although recent exceptions show that China and India that are considered Economies in Transition continue to increase their CO₂ per capita as a result of the boost in their economies.

2.7 CHAPTER SUMMARY

The evolution of the climate change establishments is seen to have tremendously helped in reducing the amount of GHG emission in the atmosphere. The Kyoto Protocol which commits developed countries to reduce their emissions and also creates an active global participating environment but with its first phase ending in December 2012, uncertainties amongst the developed countries continue to increase and this is evident with the resignation of Canada backed by Japan and Germany, increased levels of emission in countries without reduction target, the huge financial demand on developed countries and has resulted in the failing of the Kyoto Protocol.

The relation between energy demand in the various national communication sectors and population also discussed shows that in most cases population may not be the driving force for increase in energy consumption.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

Fossil fuels availability and wide acceptance has contributed massively to the energy generation of the world. The objective of this chapter is to outline the procedure to determine the carbon credits earned or required for CO₂e offsetting as a result of the carbon dioxide equivalent emissions reduce or released from the electricity generated by the utilization of fossil fuels in 28 countries on four continents including North America, Asia and Oceania, Europe and Eurasia and Africa. The carbon dioxide equivalent emissions generated in the Annex I countries (inscribed in Annex B) within the Kyoto Protocol commitment period of 2008-2012 will be compared to their emission baselines. The countries and continents to be analysed are given below:

1. **NORTH AMERICA:** The Annex I member countries to be considered on this continent are the United States of America and Canada.
 - The analysis for the United States of America would be centred on determining the total carbon dioxide equivalent emissions produced within the country will be compared to its base year emission set by the UNFCCC but will not be analysed in relation to its Kyoto Protocol emission target. This is because United States of America is not legally bound by the Kyoto Protocol as it has indicated its intention not to ratify the Protocol.
 - Canada's emission within the Kyoto Protocol commitment period would be considered and comparison made to its 1990 emission baseline. The reason is that Canada remains legally bound to the Kyoto Protocol until their resignation becomes effective from December, 2012.
2. **EUROPE and EURASIA:** The considered countries on this continent are members of the Annex I and EIT (Economies in Transition) parties included in Annex I inscribed in the Annex B. They include:
 - Annex I: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Netherlands, Norway, Poland, Portugal, Sweden, Switzerland and United Kingdom.
 - EIT parties included in Annex I: Lithuania, Romania, Russian Federation, and Slovakia.
3. **ASIA and OCEANIA:** The considered countries on this continent as also members of Annex I and EIT parties. They include the following:
 - Annex I: Australia, New Zealand and Japan.

- EIT: China, India
4. **AFRICA:** The EIT country considered is :
- South Africa

The primary energy consumption by fuel data compiled by the British Petroleum will be analysed in this chapter. The power generated utilizes different fossil fuels including Natural Gas, Oil and Coal. The British Petroleum World Statistical Review Data (2012) are shown in Table 12, Table 13 and Table 14 refers Appendix B.

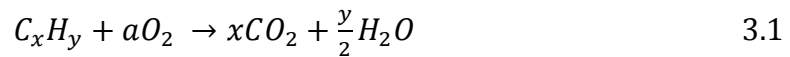
3.1.1. ASSUMPTIONS

1. Diesel Fuel will be considered as the primary consumed oil for power generation on the three continents. According to **U.S. EIA (2012)**, about 72% of the 6.87 billion barrels of petroleum used in 2011 were gasoline, diesel and jet fuel. Also the **British Petroleum World Statistical Review Data (2012)** indicates that the Primary energy from oil consumption review data was based on commercially traded fuels only excluding fuels such as wood, peat and animal waste.
2. Though different types of coal exist, Anthracite would be considered as the fossil fuel for power generation. According to the **British Petroleum World Statistical Review Data (2012)**, Hard coal and Lignite are the sources of the primary energy from coal consumption.
3. Methane, the main constituent of natural gas would also be considered.
4. The carbon dioxide emissions derived from the fossil fuels will be the only GHG emissions considered in this chapter.
5. The updated **Defra/DECC** data for the emission conversion factor is based on GHG effect from CH₄, CO₂ and N₂O quoted in kgCO₂e **Carbon Trust (2011)**, therefore water vapour (H₂O) emissions would only be shown in the combustion equation but in calculations it will not be considered.
6. The only National Communication Sector considered in this analysis is the energy supply from power stations.

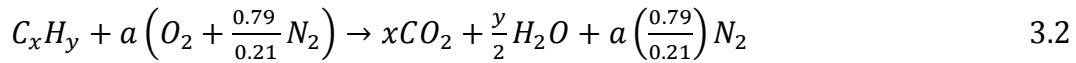
3.2 GOVERNING EQUATIONS

The generation of energy involves the combustion of fossil fuels to release the potential heat contained in the fuel when burnt in a sufficient amount of air. Therefore to achieve complete combustion of the fuel, excess air than the stoichiometric requirement of the air/fuel mixture is needed.

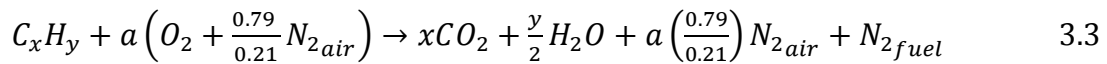
The governing general combustion equation is represented as follows:



Taking into account the Nitrogen in the air, equation (3.1) becomes



If there is Nitrogen in the fuel (e.g. Natural Gas) equation (3.2) becomes:



$$\text{Where } a = \left(x + \frac{y}{4}\right) \quad 3.4$$

Table 2 shows typical values of excess air for common fuels.

Table 2: Typical values of excess air for common fuels The Engineering Box (n.d.)

Fuel	Excess amount of Air %
Anthracite	40
Natural Gas	5-10
Oil (No 2 and No 6)	10-20

3.3 GREENHOUSE GAS CONVERSION

The use of fossil fuels in power generation leads to emissions of carbon dioxide and other GHG as highlighted in section 1.1. An equivalent quantity of CO₂ generated from a given quantity of fossil fuel quoted in tonnes is derived by multiplying the weight or mass of the fossil fuel with the global warming potential with reference to a time frame.

This is further explained thus:

$$\text{Carbon dioxide equivalent} = \text{weight of the gas} \times \text{GWP} \quad 3.5$$

Where,

Carbon dioxide equivalent (CO₂e) is expressed in tonnes.

GWP is the global warming potential.

The global warming potential of a greenhouse gas is the ratio of a direct or indirect unit mass of GHG to a unit mass of carbon dioxide over a period of time. Global warming potential can

also be said to be an index used in estimating the relative global warming atmospheric emission contributions of fossil fuels in carbon dioxide equivalents. The direct global warming potential are calculated directly from the fuel at the point of energy generation relative to CO₂ radiative forcing, SAR response function for a CO₂ pulse **Joos (2002)** and new lifetime values for a number of halocarbons while the less accurate indirect global warming potential are calculated for GHG emissions with an accuracy of ±35% **University of Michigan (n.d)**. The global warming potentials of the IPCC recognised GHG emissions are given shown in Table 3.

Table 3: Global Warming Potentials IPCC AR4 (2007)

Greenhouse Gases	GWP Values	GWP time horizon		
		20 years	100years	500years
Carbon dioxide	1	1	1	1
Methane	12	72	25	7.6
Nitrous Oxide	114	310	298	153
HFC-23 (hydrofluorocarbon)	270	1200	14800	12200
HFC-134a (hydrofluorocarbon)	14	3830	1430	435
Sulfur Hexafluoride	3200	16300	22800	32600

The **IPCC AR4 (2007)** equation to determine the global warming potential of a greenhouse gas is:

$$GWP = \frac{\int_0^T I_{gas} M_{gas} dt}{\int_0^T I_{CO_2} M_{CO_2} dt} \quad 3.6$$

Where,

I_{gas} = Instantaneous radiative forcing by gas at time t which depends on the basic molecular properties and atmospheric composition (gases, clouds, aerosols).

M_{gas} = Amount of added gas still remaining at time t depending on the lifetime of the gas, which also is a function of the amount of gas itself and other gas (Indirect effect).

T = Time horizon. Gases with lifetimes either longer or shorter than CO₂ have their GWP either increasing or decreasing with time.

For this analysis, the Carbon Trust energy conversion factors based on data published by **Carbon Trust (2011)** accounting for Carbon dioxide and Nitrous oxide GHG would be used in determining the direct carbon dioxide equivalent derived from the power generated in the United kingdom. The details of the Carbon Trust energy conversion factors are shown in Table 4.

Table 4: Energy conversion factors Carbon Trust (2011)

Fuel	Unit	kgCO₂e per Unit
Grid Electricity	kWh	0.52460
Natural Gas	kWh	0.18360
LPG	kWh	0.21470
Gas Oil	kWh	0.27857
Fuel Oil	kWh	0.26740
Burning Oil	kWh	0.24680
Diesel	kWh	0.25170
Petrol	kWh	0.24070
Industrial Coal	kWh	0.33250
Wood Pellets	kWh	0.03900

The direct carbon dioxide emissions derived from the power generated for the remaining 27 countries considered would be calculated based on the international electricity emission factors given in the 2012 guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. It should be noted that data for the other GHG were not given by Defra/DECC and therefore only carbon dioxide GHG emissions would be accounted for in these 27 countries. The emission factors are shown in Figure 10 and Figure 11.

Overseas Electricity/Heat Conversion Factors from 1990 to 2009: kgCO ₂ per kWh electricity and heat GENERATED ¹																					2009 5-yr rolling average:		Scope 2	
Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Amount used per year, kWh	Total Direct GHG		
																						kg CO ₂ per kWh	Total kg CO ₂	
European Union																								
Austria	0.24455	0.25184	0.20865	0.19352	0.20685	0.21391	0.22921	0.22744	0.20758	0.19313	0.18010	0.20089	0.19698	0.23291	0.22420	0.21861	0.21348	0.20019	0.18479	0.16323			0.19606	
Belgium	0.34442	0.34106	0.33005	0.34373	0.36385	0.35664	0.33816	0.31007	0.31497	0.27808	0.28434	0.27150	0.26626	0.27419	0.28053	0.27095	0.25978	0.24965	0.24898	0.21789			0.24945	
Bulgaria			0.47331	0.48028	0.45508	0.42776	0.41754	0.46931	0.47793	0.44464	0.43068	0.46457	0.43280	0.47025	0.47348	0.44937	0.44405	0.51896	0.49320	0.46345			0.47381	
Cyprus			0.82735	0.82810	0.83187	0.82226	0.83271	0.84131	0.84325	0.85637	0.83763	0.77743	0.75605	0.83330	0.77243	0.78837	0.75812	0.76064	0.75866	0.74427			0.76201	
Czech Republic	0.59599	0.58776	0.57380	0.58652	0.59436	0.60021	0.58317	0.58408	0.58818	0.57878	0.59521	0.58245	0.55983	0.52324	0.52421	0.52449	0.52562	0.54997	0.53716	0.51425			0.53030	
Denmark	0.47714	0.50695	0.47267	0.46031	0.47083	0.43462	0.47212	0.42825	0.39662	0.37105	0.34788	0.34437	0.34055	0.36553	0.31749	0.29262	0.35261	0.32448	0.30509	0.30275			0.31551	
Estonia	0.56083	0.54819	0.61954	0.59639	0.59712	0.67945	0.67524	0.66382	0.71410	0.70067	0.69167	0.67865	0.66173	0.71663	0.70140	0.70951	0.65181	0.74781	0.75186	0.70385			0.71297	
Finland	0.22710	0.23214	0.20508	0.22948	0.26503	0.24740	0.28065	0.26029	0.21192	0.21203	0.21143	0.24102	0.25236	0.29162	0.25304	0.19289	0.24065	0.22969	0.18712	0.20541			0.21115	
France	0.10916	0.12290	0.09810	0.06797	0.06859	0.07564	0.07918	0.07286	0.09982	0.08649	0.08395	0.07183	0.07739	0.08090	0.07912	0.09321	0.08658	0.08998	0.08675	0.08985			0.08927	
Germany	0.55265	0.56102	0.54587	0.53898	0.53855	0.52222	0.52436	0.51309	0.50585	0.48882	0.49381	0.50550	0.50768	0.43439	0.43613	0.40594	0.40425	0.46815	0.44118	0.43050			0.43000	
Greece	0.99009	0.94120	0.97127	0.94889	0.92586	0.94565	0.84186	0.81945	0.79692	0.77862	0.81733	0.83121	0.81417	0.77752	0.77643	0.77568	0.72728	0.74938	0.74486	0.72240			0.74392	
Hungary	0.41968	0.41700	0.43228	0.43262	0.43325	0.43246	0.42405	0.42802	0.42765	0.41185	0.40073	0.39368	0.39137	0.42465	0.39243	0.34065	0.34392	0.34577	0.33084	0.30206			0.33265	
Ireland	0.73998	0.74282	0.74807	0.73297	0.72967	0.72662	0.70762	0.70577	0.70252	0.69656	0.64210	0.66821	0.63488	0.60317	0.57422	0.58179	0.54545	0.50373	0.47798	0.46524			0.51484	
Italy	0.57455	0.54819	0.53510	0.52412	0.51509	0.54532	0.52398	0.51360	0.51280	0.49439	0.49768	0.48151	0.50304	0.51086	0.45886	0.44850	0.46793	0.43992	0.42129	0.38641			0.43281	
Latvia			0.27995	0.27247	0.25078	0.23886	0.26166	0.21764	0.19775	0.21797	0.19963	0.18938	0.18789	0.18250	0.16623	0.16178	0.16731	0.16405	0.16223	0.15307			0.16169	
Lithuania			0.18529	0.18524	0.21443	0.17396	0.17263	0.16828	0.17554	0.17762	0.15956	0.14698	0.12329	0.11359	0.11368	0.13601	0.13793	0.12099	0.11470	0.11115			0.12416	
Luxembourg	2.55159	2.43482	2.44648	2.42911	2.22450	1.73831	1.56562	1.05885	0.46475	0.52869	0.51692	0.45406	0.40096	0.40305	0.39410	0.38940	0.38735	0.37952	0.38163	0.38429			0.38444	
Malta			1.02049	1.38784	1.16015	0.95725	0.97330	0.93658	0.93164	0.90346	0.81902	1.00723	0.93443	0.94644	0.91332	1.03378	0.95415	1.01189	0.84871	0.85042			0.93979	
Netherlands	0.58835	0.57181	0.55952	0.57410	0.53614	0.46440	0.44310	0.42814	0.41702	0.41548	0.40002	0.41404	0.40148	0.40563	0.39551	0.38706	0.39432	0.39972	0.39208	0.37449			0.38953	
Poland	0.64058	0.63337	0.63719	0.63627	0.64082	0.67051	0.66206	0.66505	0.66291	0.66417	0.67076	0.65670	0.65554	0.65525	0.65594	0.65044	0.65729	0.65913	0.65550	0.64020			0.65251	
Portugal	0.51620	0.52043	0.62047	0.54407	0.51950	0.57240	0.43184	0.46107	0.47095	0.53864	0.47952	0.44193	0.51196	0.41325	0.45150	0.50087	0.41782	0.38462	0.38353	0.36824			0.41102	
Romania			0.40929	0.38409	0.45570	0.44006	0.44392	0.38486	0.35097	0.36582	0.39580	0.40364	0.41232	0.45072	0.41780	0.40265	0.43901	0.45349	0.43980	0.41435			0.42986	
Slovak Republic	0.37559	0.38589	0.35771	0.40975	0.35609	0.37466	0.36103	0.37698	0.35094	0.33976	0.26669	0.24116	0.21487	0.25478	0.24002	0.22900	0.22341	0.22929	0.21754	0.22172			0.22419	
Slovenia	0.35989	0.29920	0.34568	0.35878	0.32407	0.32797	0.31179	0.36540	0.37059	0.34040	0.33831	0.35348	0.37149	0.36707	0.34073	0.34459	0.35496	0.36665	0.32884	0.31603			0.34221	
Spain	0.42715	0.42161	0.47435	0.41584	0.41079	0.45343	0.35774	0.39197	0.38092	0.44439	0.42994	0.38172	0.43402	0.37838	0.38176	0.39684	0.36875	0.38709	0.32658	0.29878			0.35551	
Sweden	0.04827	0.05870	0.05098	0.05204	0.05628	0.05001	0.07390	0.05079	0.05319	0.04894	0.04152	0.04205	0.05170	0.05939	0.05098	0.04404	0.04796	0.04004	0.04007	0.04314			0.04305	
European Union - 27			0.43878	0.41941	0.41931	0.41375	0.40612	0.39487	0.39044	0.38159	0.38102	0.37639	0.38003	0.37355	0.36575	0.35830	0.36246	0.37303	0.35485	0.33891			0.35751	
SUBTOTAL																								

Figure 10: Overseas Electricity/Heat conversion factors from 1990-2009 for the European Union Countries Defra/DECC (2012)

Overseas Electricity/Heat Conversion Factors from 1990 to 2009: kgCO ₂ per kWh electricity and heat GENERATED ¹																				Scope 2			
Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 5-yr rolling average:	Total Direct GHG	
																					Amount used per year, kWh	kg CO ₂ per kWh	Total kg CO ₂
Other countries																							
Australia	0.81518	0.81924	0.82552	0.81015	0.80408	0.80987	0.82342	0.82589	0.86353	0.86464	0.85303	0.85962	0.92875	0.91783	0.89880	0.90971	0.92562	0.87631	0.85560	0.85293		0.88403	
Brazil			0.06099	0.05541	0.05117	0.05530	0.05711	0.06222	0.06222	0.08221	0.08761	0.10335	0.08525	0.07886	0.08503	0.08395	0.08100	0.07277	0.08885	0.06413		0.07814	
Canada	0.20345	0.19565	0.20469	0.18298	0.17955	0.18436	0.17827	0.19764	0.22119	0.21215	0.22195	0.23110	0.21608	0.22851	0.21387	0.20018	0.20129	0.19731	0.18772	0.16723		0.19075	
People's Rep. of China			0.79424	0.79386	0.76781	0.80280	0.82056	0.80406	0.82292	0.79757	0.76459	0.73962	0.74821	0.77567	0.80522	0.78720	0.78746	0.75823	0.74424	0.74257		0.76394	
Chinese Taipei			0.50213	0.52515	0.52356	0.53346	0.53960	0.57041	0.57744	0.59576	0.62638	0.64095	0.63133	0.65053	0.64631	0.65129	0.65917	0.65530	0.65024	0.63478		0.65016	
Croatia			0.32418	0.32746	0.24922	0.27159	0.25273	0.29745	0.32230	0.30585	0.30327	0.31286	0.35666	0.37967	0.30001	0.31391	0.32018	0.38487	0.34149	0.28339		0.32877	
Egypt			0.52968	0.50320	0.46648	0.44331	0.43277	0.44226	0.46748	0.45457	0.41183	0.38101	0.43669	0.43248	0.47316	0.47403	0.47343	0.45041	0.45976	0.46553		0.46463	
Gibraltar			0.77368	0.77337	0.75148	0.76592	0.75199	0.77284	0.76592	0.76594	0.75981	0.75378	0.75998	0.75451	0.76593	0.76066	0.77101	0.77087	0.75670	0.73952		0.75975	
Hong Kong, China			0.82063	0.86204	0.86434	0.85526	0.82323	0.72359	0.73968	0.71594	0.71182	0.71996	0.72516	0.79505	0.74912	0.75544	0.75391	0.77473	0.75742	0.76297		0.76089	
Iceland	0.00052	0.00049	0.00046	0.00080	0.00080	0.00162	0.00119	0.00109	0.00292	0.00375	0.00062	0.00060	0.00061	0.00062	0.00061	0.00061	0.00054	0.00137	0.00075	0.00042		0.00074	
India			0.85618	0.88191	0.85089	0.90138	0.94329	0.91449	0.89732	0.90141	0.92042	0.92114	0.90726	0.89223	0.93093	0.92283	0.92079	0.94335	0.95426	0.95141		0.93853	
Indonesia			0.60357	0.69108	0.61301	0.59149	0.60878	0.65846	0.63403	0.65412	0.65345	0.68138	0.67764	0.71907	0.70139	0.71644	0.73807	0.77490	0.75190	0.74569		0.74540	
Israel	0.80618	0.80460	0.79071	0.80623	0.80202	0.80501	0.80996	0.80363	0.74794	0.75011	0.74893	0.75195	0.81180	0.80461	0.78521	0.77798	0.75825	0.75536	0.71229	0.69488		0.73975	
Japan	0.43450	0.42494	0.43089	0.41198	0.42981	0.41097	0.40801	0.39353	0.38125	0.39678	0.40059	0.40149	0.42208	0.44443	0.42716	0.42912	0.41845	0.45218	0.43761	0.41471		0.43041	
DPR of Korea			0.54278	0.50499	0.50767	0.48121	0.52056	0.55805	0.49966	0.55241	0.58359	0.58260	0.56801	0.54177	0.52846	0.52180	0.53320	0.46857	0.48136	0.49886		0.50076	
Malaysia			0.59831	0.57504	0.52580	0.52353	0.52519	0.46637	0.50533	0.48742	0.47591	0.50017	0.54655	0.49171	0.53793	0.60496	0.60700	0.61065	0.65592	0.64865		0.62544	
Mexico	0.54929	0.56641	0.54057	0.54536	0.59322	0.53852	0.53357	0.55609	0.57415	0.55119	0.55938	0.56132	0.55840	0.57095	0.49545	0.50931	0.48224	0.47915	0.43032	0.45498		0.47120	
New Zealand	0.10745	0.11640	0.14990	0.11989	0.09701	0.08695	0.11034	0.15795	0.14033	0.17032	0.15976	0.20196	0.17285	0.20987	0.19293	0.23357	0.22815	0.19415	0.21283	0.16650		0.20704	
Norway	0.00342	0.00453	0.00387	0.00418	0.00516	0.00449	0.00629	0.00548	0.00550	0.00600	0.00406	0.00583	0.00530	0.00833	0.00712	0.00556	0.00695	0.00745	0.00641	0.01729		0.00873	
Pakistan			0.39319	0.38423	0.39115	0.40492	0.44263	0.45374	0.41143	0.46783	0.47945	0.46297	0.44283	0.37076	0.39726	0.38000	0.41318	0.43265	0.45112	0.45772		0.42693	
Philippines			0.42143	0.41381	0.43150	0.45707	0.47178	0.49519	0.50385	0.45130	0.49425	0.47972	0.44946	0.45262	0.45225	0.49548	0.43303	0.44776	0.46677	0.47816		0.46824	
Russian Federation			0.31939	0.29111	0.29602	0.29176	0.34188	0.32832	0.32636	0.32696	0.32076	0.32148	0.32666	0.32930	0.32457	0.32497	0.32857	0.32250	0.32551	0.31740		0.32379	
Saudi Arabia			0.81349	0.81957	0.81428	0.81344	0.80052	0.80723	0.81351	0.81022	0.80638	0.77753	0.75087	0.73716	0.75414	0.73916	0.74909	0.72611	0.73561	0.75723		0.74144	
Singapore			0.84129	1.00411	0.95658	0.91620	0.87312	0.76485	0.73182	0.75584	0.76198	0.72472	0.66428	0.59734	0.56626	0.54348	0.53026	0.52807	0.52144	0.51886		0.52842	
South Africa			0.85531	0.88052	0.86361	0.87813	0.86067	0.86949	0.92747	0.88973	0.89303	0.82892	0.81941	0.84908	0.87118	0.85141	0.83151	0.82719	0.94774	0.92590		0.87675	
Switzerland	0.03495	0.03896	0.04035	0.03183	0.03102	0.03373	0.03769	0.03536	0.04177	0.03507	0.03597	0.03569	0.03902	0.03904	0.04027	0.04613	0.04549	0.04099	0.04042	0.03993		0.04259	
Thailand			0.64630	0.63008	0.62341	0.60306	0.60952	0.63384	0.60814	0.59624	0.56701	0.56632	0.54766	0.53573	0.54281	0.53541	0.51092	0.54640	0.52886	0.51338		0.52699	
Turkey	0.56842	0.56675	0.55701	0.50511	0.55039	0.51248	0.52095	0.52474	0.53042	0.54890	0.51886	0.54389	0.47199	0.44407	0.41938	0.42638	0.43822	0.47821	0.49528	0.47993		0.46360	
Ukraine			0.39057	0.40700	0.38143	0.38344	0.33347	0.32350	0.33200	0.33911	0.34682	0.32954	0.32475	0.38099	0.31648	0.33115	0.34551	0.36025	0.38611	0.37396		0.35940	
United States			0.58714	0.58222	0.58117	0.57923	0.58409	0.61645	0.60365	0.59049	0.58589	0.61681	0.56733	0.57082	0.57113	0.56964	0.54230	0.54921	0.53519	0.50817		0.54090	
Africa			0.67255	0.68359	0.67656	0.68530	0.66909	0.67559	0.70264	0.67135	0.65765	0.61569	0.61823	0.63284	0.64358	0.63071	0.62525	0.61472	0.66554	0.64326		0.63590	
Latin America			0.18378	0.17292	0.16444	0.16725	0.16409	0.16585	0.17208	0.17112	0.17317	0.18222	0.17921	0.17972	0.17760	0.17761	0.17820	0.17612	0.18409	0.17480		0.17816	
Middle East			0.69777	0.70472	0.71670	0.71420	0.70387	0.70234	0.69832	0.70886	0.70740	0.71431	0.69958	0.67683	0.69302	0.68845	0.69235	0.67927	0.69092	0.69026		0.68825	
Non-OECD Europe and Eurasia			0.35120	0.33026	0.33244	0.32603	0.35561	0.34429	0.34417	0.34290	0.34382	0.34067	0.34490	0.35439	0.34244	0.34253	0.35344	0.34906	0.35297	0.34412		0.34842	
SUBTOTAL																						0	
GRAND TOTAL																							

Figure 11: Overseas Electricity/Heat conversion factors from 1990-2009 for Non-European Union Countries Defra/DECC (2012)

3.4 PROCEDURE OF METHODOLOGY

The process flowchart describing the procedure in deriving the carbon credits generated or required to offset excess GHG emissions is shown in Figure 12.

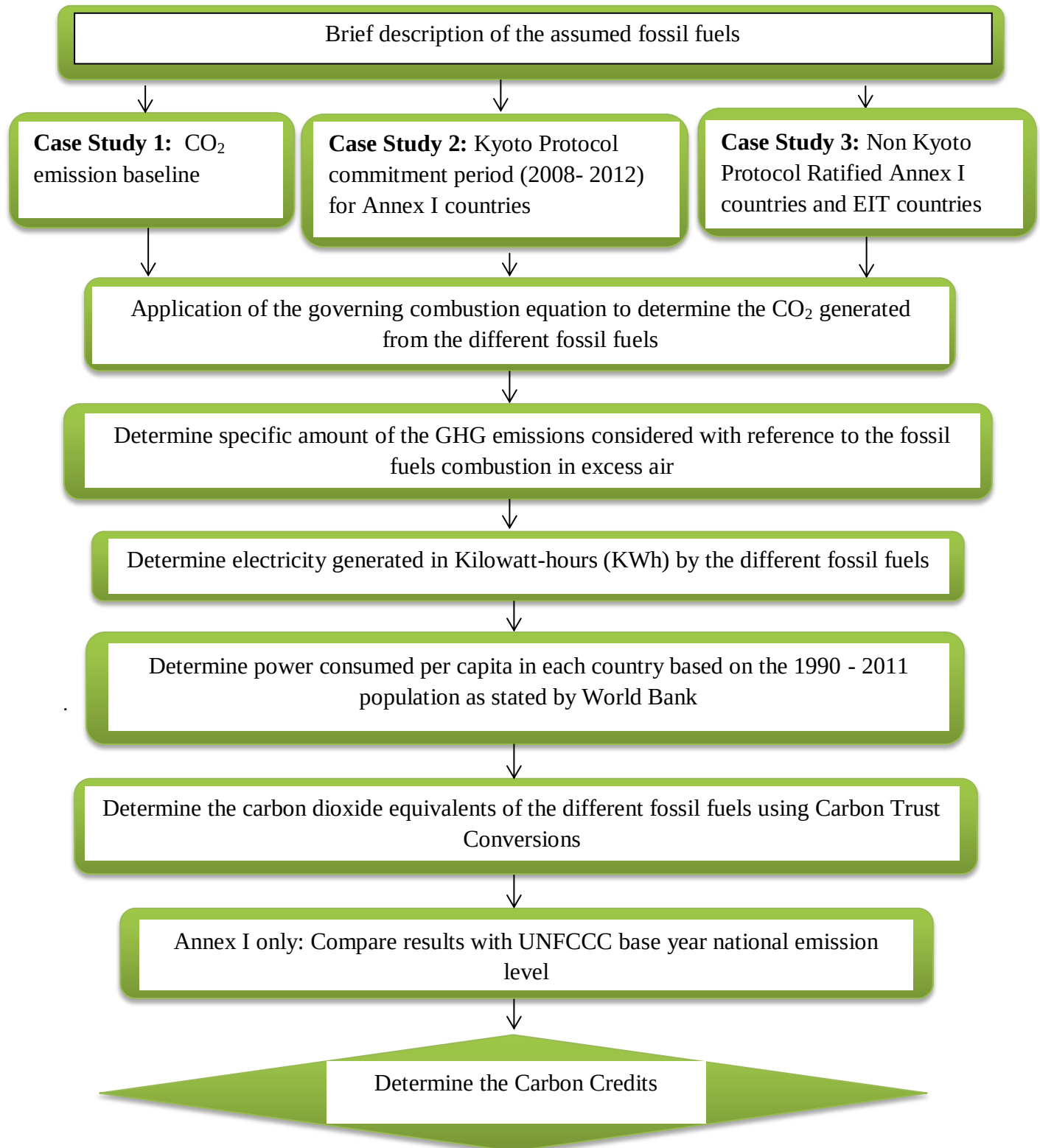


Figure 12 : Process flowchart for carbon credit determination

3.4.1 FOSSIL FUELS

The fossil fuel utilized in this chapter are Diesel Fuel, Natural Gas and Anthracite coal. These fuels generated carbon dioxide emissions which when released in the atmosphere contribute to climate change and global warming.

1. **Natural Gas:** The main constituent of natural gas is methane, a greenhouse gas with chemical formulae of CH_4 . This clean gas and does not produce as much CO_2 on combustion when compared with the other fossil fuels. As indicated in Table 1, its global warming potential is 12 times more than CO_2 making it a more potent GHG.
2. **Diesel fuel:** This is a petroleum based fuel used for electricity generation as an alternative fuel in large scale commercial combustion and to power vehicles. It is a heavy, less volatile distillate fuel oil produced through the fractional distillation process of crude oil. It is also a blend of paraffins, naphthalenes, olefins and aromatics in different ratios depending on the temperature of the region as it is a good start-up fuel. Its average chemical formulae is $\text{C}_{12}\text{H}_{23}$ ranging from $\text{C}_{10}\text{H}_{20}$ to $\text{C}_{15}\text{H}_{28}$ **Diff en (n.d)**.
3. **Anthracite coal:** This type of coal is a fossil fuel and a high-molar-mass carbon compound with a composition of about 95% carbon by weight with a heating value of about 15million Btu per tonne **Rockdoctor (2011)**. It is a hard, brittle and lustrous coal with a low volatile matter percentage and moisture content of less than 15% **U.S. EIA (n.d)**. The standard grade of anthracite coal used for power generation has a chemical formulae are $\text{C}_{52}\text{H}_{16}\text{O}_{(s)}$ **MHF (2012)**. Coal utilized for power generation must be pulverized.

3.4.2 CASE STUDY 1 (EMISSION BASELINES)

The base year set by the Kyoto Protocol for 25 Annex I countries and parties included in Annex I is considered as the CO_2e (carbon dioxide equivalents) emission limit year. The complied consumption by fuel data **British Petroleum (2012)** is used to calculate the electricity generated by each examined country based on their population for the CO_2e emission base year as set by the Kyoto Protocol.

As described in section 2.2.3, the Annex B emissions target and the Party's emissions of GHGs in the base year determine the Party's initial assigned amount for the Kyoto Protocol's five-year first commitment period (2008 – 2012). The quantity of the initial assigned amount is denominated in individual units, called assigned amount units (AAUs), each of which

represents an allowance to emit one metric tonne of carbon dioxide equivalent (TCO₂e) **UNFCCC (2008)**. The Assigned amounts for each considered country is given in Figure 13.

ANNEX I Party	Tonnes of CO ₂ e	ANNEX I Party	Tonnes of CO ₂ e
Australia*		Luxembourg	47,402,996
Austria	343,866,009	Monaco	495,221
Belgium	673,995,528	Netherlands	1,001,262,141
Bulgaria	610,045,827	New Zealand	309,564,733
Canada	2,791,792,771	Norway	250,576,797
Czech Republic	893,541,801	Poland	2,648,181,038
Denmark	276,838,955	Portugal	381,937,527
Estonia	196,062,637	Romania	1,279,835,099
European Community	19,621,381,509	Russian Federation	16,617,095,319
Finland	355,017,545	Slovakia	331,433,516
France	2,819,626,640	Slovenia	93,628,593
Germany	4,868,096,694	Spain	1,666,195,929
Hungary	542,366,600	Sweden	375,188,561
Iceland	18,523,847	Switzerland	242,838,402
Ireland	314,184,272	Ukraine	4,604,184,663
Japan	5,928,257,666		
Latvia	119,182,130	United Kingdom of	
Liechtenstein	1,055,623	Great Britain and	3,412,080,630
Lithuania	227,306,177	Northern Ireland	

* assigned amounts of Units (TCO₂e) not available

Figure 13: Assigned amounts of Tonnes of carbon dioxide equivalent UNFCCC (2008)

Therefore, the assigned amounts for each country will be compared to the CO₂e emissions generated from the calculated electricity generated by each country. The UNFCCC total national anthropogenic carbon dioxide equivalent emission base year level by the initial review given in Table 5 is used to calculate the assigned amounts units. The complied British Petroleum World Statistical Review Data consumption by fuel data (2012) used for this analysis is given in Table 12; Table 13 and Table 14 refer Appendix B.

The Kyoto Protocol CO₂e emission base year and the total national anthropogenic values are shown in Table 5.

Table 5: CO₂e emission base year and total national anthropogenic values UNFCCC (2012)

Continents	Countries	Base Year for CO₂, CH₄, N₂O	Base Year level of total national emissions by the initial review (TCO₂e)
North America	Canada	1990	593,998,462
Europe	Belgium	1990	145,728,763
	Bulgaria	1988	132,618,658
	Croatia	1990	31,321,790
	Czech Republic	1990	194,248,218
	Denmark	1990	69,978,070
	Estonia	1990	42,622,312
	Finland	1990	71,003,509
	Germany	1990	1,232,429,543
	Hungary	1985-1987	115,397,149
	Ireland	1990	55,607,836
	Latvia	1990	25,909,159
	Lithuania	1990	49,414,386
	Netherlands	1990	213,034,498
	Norway	1990	49,619,168
	Austria	1990	79,049,657
	Poland	1988	563,442,774
	Portugal	1990	60,147,642
	Romania	1989	278,225,022
	Russian Federation	1990	3,323,419,064
	Slovakia	1990	72,050,764
	Sweden	1990	72,151,646
	Switzerland	1990	52,790,957
	United Kingdom	1990	779,904,144
Asia and Oceania	Australia	1990	547,699,841
	Japan	1990	1,261,331,418
	New Zealand	1990	61,912,947

3.4.2 CASE STUDY 2(KYOTO PROTOCOL 2008-2012)

This case study centres on the carbon dioxide equivalent emissions produced within the Kyoto Protocol commitment years 2008-2012. The British Petroleum provides information on the world statistical review primary energy consumption by fuels data up to 2011 and therefore, analysis would be made for 2008-2011.

The British Petroleum World Statistical Review Data (2012) would be used to determine the electricity generated by the assumed fossil fuels for 2008-2011 for 24 countries excluding the United States of America, China, India and South Africa listed in Table 12, Table 13 and Table 14 refers Appendix B. Each Annex I country and parties included in Annex I total carbon dioxide equivalent emissions calculated from the combustion of the different fossil fuels will be compared to their assigned amount units for each country in Figure 15 according to the Decision 13/CMP.1UNFCCC (2006).

This would determine the carbon credits earned if their carbon emissions have been successfully reduced below their assigned amounts or emission levels. On the other, if these countries have not been able to meet their emission reduction targets, they will be required to purchase carbon credits to offset their excess carbon dioxide equivalent emissions as long as they remain legally bound to the Kyoto Protocol.

The Kyoto protocol target for GHG emission reduction for Annex I countries and parties included in Annex I are shown in Table 6.

Table 6: Quantified emission limitation or reduction targets for Annex I countries and parties included in Annex I as contained in Annex B to the Kyoto Protocol UNFCCC (2008)

Annex 1 Countries	Emission limitation or baseline reduction target % (expressed in relation to total GHG emissions in the base year or period inscribed in Annex B to the Kyoto Protocol)
Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Germany, Ireland, Lithuania, Netherlands, Portugal, Romania, Slovakia, Switzerland, United Kingdom and Northern Ireland	-8
Canada, Hungary, Japan, Poland	-6

New Zealand, Russian Federation	0
Norway	+1
Australia	+8
United States of America**	-7

** represents the country that has not ratified the Kyoto Protocol.

3.4.3 CASE STUDY 3 (KYOTO PROTOCOL NON RATIFIED ANNEX I COUNTRIES AND EIT COUNTRIES)

The countries analysed in this section are considered the largest CO₂e emitting countries in the world due to the high level consumption of fossil fuel recorded in the World Statistical Review Data **British Petroleum (2012)**.

The Annex I country considered in this case study is the United States of America; though included in Annex B and assigned an emission target, it has indicated its intention not to ratify the Kyoto Protocol. Also, the EIT countries examined are China, India and South Africa that has no Kyoto Protocol emission targets but has experience tremendous economic growth on the platform of the CDM projects in the country.

The electricity generated in these countries would be calculated to determine the CO₂e emissions. The effects of these countries statues to the Kyoto Protocol would be analysed to determine the increasing or decreasing level of GHG emissions with regards to their 1990 to 2011 population census complied by **World Bank (2012)**. Table 15, Table 16 and Table 17 shows the population for 1990 -2011 of the 28 considered countries.

The World Statistical Review Data for Natural Gas consumption, Total Oil consumption and Total coal consumption for 1990-2011 **British Petroleum (2012)** is given in Table 12, Table 13 and Table 14 refer Appendix.

3.5 APPLICATION OF THE GOVERNING COMBUSTION EQUATION TO DETERMINE THE CO₂ GENERATED FROM THE DIFFERENT FOSSIL FUELS.

3.5.1 Natural Gas (CH₄)

Using equation 3.2 and 3.4:

$$C_xH_y + a \left(O_2 + \frac{0.79}{0.21} N_2 \right) \rightarrow xCO_2 + \frac{y}{2}H_2O + a \left(\frac{0.79}{0.21} \right) N_2 \quad 3.2$$

$$a = \left(x + \frac{y}{4} \right) \quad 3.4$$

If $x = 1, y = 4$

Submitting the values into equation 3.4 we have,

$$a = \left(1 + \frac{4}{4} \right)$$

$$a = 2$$

Therefore, equation 3.2 becomes

$$CH_4 + 2 \left(O_2 + \frac{0.79}{0.21} N_2 \right) \rightarrow CO_2 + 2H_2O + 2 \left(\frac{0.79}{0.21} \right) N_2 \quad 3.7$$

$$CH_4 + 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + (7.52)N_2 \quad 3.8$$

Assuming an excess air of 10% as shown in Table 1,

$$\frac{(100 + 10)}{100} = \frac{110}{100} = 1.1$$

Equation 3.8 becomes,

$$CH_4 + 1.1 \times 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + 0.2O_2 + 8.272N_2 \quad 3.9$$

$$CH_4 + 2.2O_2 + 8.272N_2 \rightarrow CO_2 + 2H_2O + 0.2O_2 + 8.272N_2 \quad 3.10$$

Equation 3.10 indicates that for complete combustion of natural gas with 10% excess air, one mole of methane produces GHG consisting of one mole of carbon dioxide and two moles of water vapour.

3.5.2 Diesel Oil ($C_{12}H_{23}$)

Using equation 3.2 and 3.4:

$$C_xH_y + a \left(O_2 + \frac{0.79}{0.21} N_2 \right) \rightarrow xCO_2 + \frac{y}{2} H_2O + a \left(\frac{0.79}{0.21} \right) N_2 \quad 3.2$$

$$a = \left(x + \frac{y}{4} \right) \quad 3.4$$

If $x = 12, y = 23$

Submitting the values into equation 3.4 we have,

$$a = \left(12 + \frac{23}{4} \right)$$

$$a = 17.75$$

Therefore, equation 3.2 becomes,

$$C_{12}H_{23} + 17.75 \left(O_2 + \frac{0.79}{0.21} N_2 \right) \rightarrow 12CO_2 + 11.5H_2O + 17.75 \left(\frac{0.79}{0.21} \right) N_2 \quad 3.11$$

$$C_{12}H_{23} + 17.75(O_2 + 3.76N_2) \rightarrow 12CO_2 + 11.5H_2O + 17.75(3.76)N_2 \quad 3.12$$

Assuming an excess air of 20% as shown in Table 1,

$$\frac{(100 + 20)}{100} = \frac{120}{100} = 1.2$$

Equation 3.12 becomes,

$$C_{12}H_{23} + 1.2 \times 17.75(O_2 + 3.76N_2) \rightarrow 12CO_2 + 11.5H_2O + 7.1O_2 + 80.088N_2 \quad 3.13$$

$$C_{12}H_{23} + 21.3O_2 + 80.088N_2 \rightarrow 12CO_2 + 11.5H_2O + 7.1O_2 + 80.088N_2 \quad 3.14$$

Equation 3.14 indicates that for complete combustion with 20% excess air, one mole of diesel produces GHG consisting of twelve moles of carbon dioxide and 11.5 moles of water vapour.

3.5.3 Anthracite Coal ($C_{52}H_{16}O_{(s)}$)

Using equation 3.2 and 3.4:

$$C_xH_y + a \left(O_2 + \frac{0.79}{0.21} N_2 \right) \rightarrow xCO_2 + \frac{y}{2} H_2O + a \left(\frac{0.79}{0.21} \right) N_2 \quad 3.2$$

$$a = \left(x + \frac{y}{4} \right) \quad 3.4$$

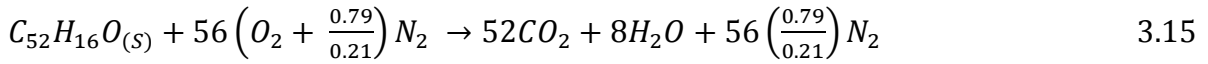
If $x = 52, y = 16$

Submitting the values into equation 3.4 we have,

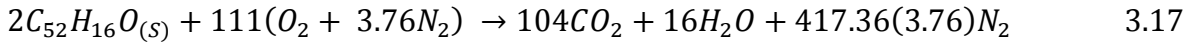
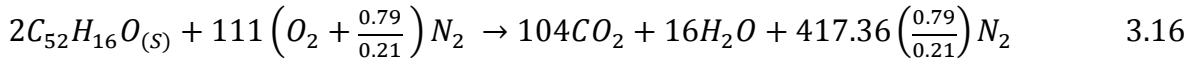
$$a = \left(52 + \frac{16}{4}\right)$$

$$a = 56$$

Therefore, equation 3.2 becomes,



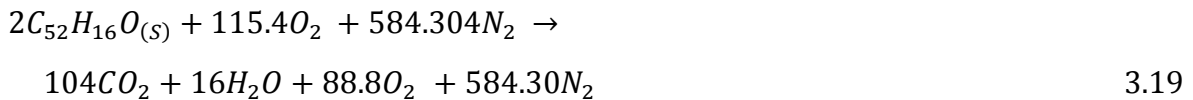
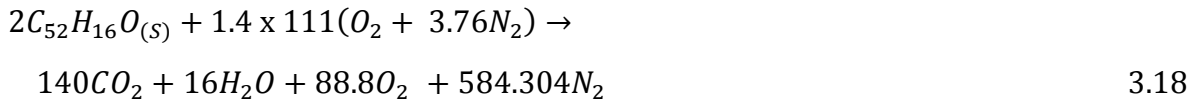
Balancing equation 3.15, we have



Assuming an excess air of 40% as shown in Table 1,

$$\frac{(100 + 40)}{100} = \frac{140}{100} = 1.4$$

Equation 3.15 becomes,



Equation 3.19 indicates that for complete combustion of standard anthracite coal with 40% excess air, two mole of coal produces GHG consisting of one hundred and four moles of carbon dioxide and sixteen moles of water vapour.

3.6 DETERMINE SPECIFIC AMOUNT OF THE GHG EMISSIONS CONSIDERED WITH REFERENCE TO THE FOSSIL FUELS COMBUSTION IN EXCESS AIR

The primary consumption by fuel data British Petroleum (2012) would be used to determine the number of moles contained in a tonne of the considered fossils fuels. The balanced combustion equation for the fossils fuels will then be used to determine the specific amounts of the different GHG emitted. Table 7 shows the United Kingdom primary energy consumption by fuel data for 2011.

Table 7: United Kingdom primary energy consumption by fuel data for 2011 British Petroleum (2012)

Country	Fossil fuels		
	Natural Gas (Million Tonnes of Oil equivalent)	Oil (Million Tonnes)	Coal (Million Tonnes of oil equivalent)
United Kingdom	72.2	71.6	30.8

3.6.1 Sample Calculations

3.6.1.1 Natural Gas

Determine the number of moles in 72.2 million tonnes of oil equivalent

1 Tonne of Oil equivalent = 42GigaJoules (GJ)

Therefore, 72.2 million tonnes of oil equivalent contains

$$= \frac{(72.2 \times 10^6) \text{ Tonne of Oil equivalent} \times 42 \text{ GJ}}{1 \times 10^6 \text{ Tonne of Oil equivalent}} \quad 3.20$$

$$= 3032.4 \text{ GJ}$$

But,

1 cubic meter of Natural gas = 38.2 MJ Calorific value of Natural gas **National Grid (2012)**

Converting 3032.4 GigaJoules to MegaJoules (MJ), we have

$$= \frac{3032.4 \text{ GJ} \times 1000 \text{ MJ}}{1 \text{ GJ}} \quad 3.21$$

$$= 3032400 \text{ MJ}$$

Therefore, the amount of cubic meters (m³) in 72.2 Million Tonnes of Oil equivalent will be,

$$= \frac{3032400MJ \times 1m^3}{38.2MJ} \quad 3.22$$

$$= 79382.19895m^3 \text{ of Natural Gas}$$

Then,

1000 litres = 1 cubic meter

79382.19895m³ of Natural gas will contain

$$= \frac{79382.19895m^3 \times 1000litres}{1m^3} \quad 3.23$$

$$= 79382198.95litres$$

But,

1 litre = 1000kg

Therefore, 79382198.95litres will be,

$$= \frac{79382198.95litres \times 1000000g}{1 litre} \quad 3.24$$

$$= 7.938219895 \times 10^3 g$$

Then to convert from grams (g) to moles, we consider the molar mass of methane

Molar mass of methane $CH_4 = 12g + (4 \times 1) = 16g/mol$

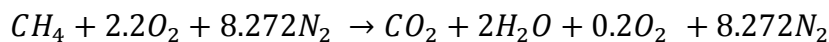
Therefore,

$$= \frac{7.938219895 \times 10^3 g}{16g/mol} \quad 3.25$$

$$= 4.96 \times 10^{12} \text{ moles of Natural Gas}$$

Therefore, 72.2 Million Tonnes of Oil equivalent contains **4.96×10^{12} moles of Natural Gas.**

From Equation 3.10



Therefore, complete combustion of 4.96×10^{12} mole of Natural Gas in 10% excess air will produce GHG consisting of **4.96×10^{12} moles of CO_2** and **9.92×10^{12} moles of H_2O .**

3.6.1.2 Diesel Fuel

Determine the number of moles in 71.6 Million Tonnes

1 Metric Tonne = 1000 kilogram (kg)

Therefore, 71.6 *Million Tonnes*

$$= \frac{71.6 \times 10^6 \text{ Tonnes} \times 1000 \text{ kg}}{1 \text{ Tonne}} \quad 3.26$$

$$= 7.16 \times 10^{10} \text{ kg}$$

Density of Diesel Fuel = 900 kg/m^3 Isidoro (2012)

Then, $7.16 \times 10^{10} \text{ kg}$ will contain

$$= \frac{71.6 \times 10^{10} \text{ kg}}{900 \text{ kg/m}^3} \quad 3.27$$

$$= 79555555.56 \text{ m}^3$$

Then,

1000 litres = 1 cubic meter

79555555.56 m^3 of Diesel Fuel will contain

$$= \frac{79555555.56 \text{ m}^3 \times 1000 \text{ litres}}{1 \text{ m}^3} \quad 3.28$$

$$= 7.96 \times 10^{10} \text{ litres}$$

But,

1 litre = 1000g

Therefore, $7.96 \times 10^{10} \text{ litres}$ will be,

$$= \frac{7.96 \times 10^{10} \text{ litres} \times 1000000 \text{ g}}{1 \text{ litre}} \quad 3.29$$

$$= 7.96 \times 10^{16} \text{ g}$$

Then to convert from grams (g) to moles, we consider the molar mass of diesel fuel

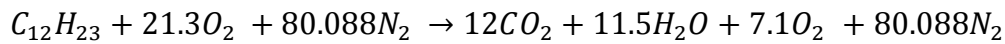
Molar mass of diesel fuel $C_{12}H_{23} = (12 \times 12g) + (4g \times 1) = 167g/mol$

Therefore,

$$\begin{aligned} &= \frac{7.96 \times 10^{16}g}{167g/mol} \\ &= 4.73 \times 10^{14} \text{ moles of Diesel Fuel} \end{aligned} \quad 3.30$$

Therefore, 71.6 Million Tonnes contains **4.73×10^{14} moles of Diesel Fuel.**

From Equation 3.14



Therefore, complete combustion of 4.73×10^{14} moles of Diesel Fuel in 20% excess air will produce GHG consisting of **5.676×10^{15} moles of CO_2 and 5.4395×10^{15} moles of H_2O .**

3.6.1.3 Anthracite Coal

Determine the number of moles in 30.8 million tonnes of oil equivalent

1 Tonne of Oil equivalent = 1.5 Tonnes of Hard Coal

Therefore,

30.8 Million Tonnes of oil equivalent contain

$$= \frac{(30.8 \times 10^6) \text{ Tonne of Oil equivalent} \times 1.5 \text{ Tonnes}}{1 \times 10^6 \text{ Tonne of Oil equivalent}} \quad 3.31$$

$$= 46200000 \text{ Tonnes}$$

Then,

1 Metric Tonne = 1000 kilogram (kg)

Therefore, 46200000 Tonnes

$$\begin{aligned} &= \frac{46200000 \text{ Tonnes} \times 1000kg}{1 \text{ Tonne}} \\ &= 4.62 \times 10^{10} kg \end{aligned} \quad 3.32$$

Density of Anthracite Coal = 850 kg/m^3 The Engineering box (n.d.)

Then, $4.62 \times 10^{10} \text{ kg}$ will contain,

$$\begin{aligned} &= \frac{4.62 \times 10^{10} \text{ kg}}{850 \text{ kg/m}^3} \\ &= 54352941.18 \text{ m}^3 \end{aligned} \quad 3.33$$

Then,

1000 litres = 1 cubic meter

54352941.18 m^3 of anthracite coal will contain

$$\begin{aligned} &= \frac{54352941.18 \text{ m}^3 \times 1000 \text{ litres}}{1 \text{ m}^3} \\ &= 5.435294118 \times 10^{10} \text{ litres} \end{aligned} \quad 3.34$$

But,

1 litre = 1000kg

Therefore, $5.435294118 \times 10^{10} \text{ litres}$ will be,

$$\begin{aligned} &= \frac{5.435294118 \times 10^{10} \text{ litres} \times 1000000 \text{ g}}{1 \text{ litre}} \\ &= 5.435294118 \times 10^{16} \text{ g} \end{aligned} \quad 3.35$$

Then to convert from grams (g) to moles, we consider the molar mass of anthracite coal

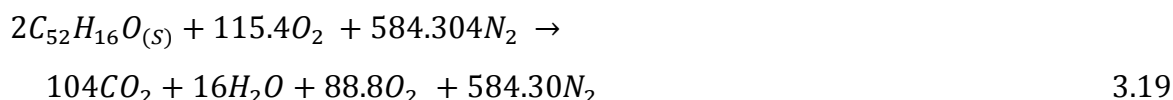
Molar mass of anthracite coal $\text{C}_{12}\text{H}_{16}\text{O}_{(s)} = (12 \times 12 \text{ g}) + (16 \times 1) + 16 = 168 \text{ g/mol}$

Therefore,

$$\begin{aligned} &= \frac{5.435294118 \times 10^{16} \text{ g}}{168 \text{ g/mol}} \\ &= 8.285509326 \times 10^{13} \text{ moles} \\ &= 8.29 \times 10^{13} \text{ moles of Anthracite Coal} \end{aligned} \quad 3.36$$

Therefore, 30.8 Million Tonnes of Oil equivalent contains **8.29×10^{13} moles of Anthracite Coal.**

From Equation 3.19



Therefore, complete combustion of 1.658×10^{14} moles of standard Anthracite Coal in 40% excess air will produce GHG consisting of **1.72432×10^{16} moles of CO_2 and 2.6528×10^{15} moles of H_2O .**

3.7 ELECTRICITY CALCULATIONS BASED ON THE AMOUNT FOR THE PRIMARY CONSUMPTION OF EACH FOSSIL FUEL

The British Petroleum World Statistical Review Data (2012) will be used in analysis. To present a defined sample calculation, the United Kingdom's primary energy consumption by fuel data for 2011 would be considered.

Table 8 shows the United Kingdom primary energy consumption by fuel data and the Total electricity generated in 2011.

Table 8: United Kingdom primary energy consumption by fuel data and Total electricity generated in 2011 British Petroleum (2012)

Country	Fossil fuels			Total Electricity Generated kWh
	Natural Gas (Million Tonnes of Oil equivalent)	Oil (Million Tonnes)	Coal (Million Tonnes of oil equivalent)	
United Kingdom	72.2	71.6	30.8	2.1×10^{12}

3.7.1 Sample Calculations

The British Petroleum conversion factor (2012) will be utilized.

3.7.1.1 Natural gas

1 Million Tonnes of Oil equivalent (Mtoe) = 39.7 trillion British thermal unit (Btu)

Therefore, **(72.2×10^6) Tonnes of Oil equivalent**

$$= \frac{(72.2 \times 10^6) \text{ Tonne of Oil equivalent} \times 39.7 \times 10^{12} \text{ Btu}}{1 \times 10^6 \text{ Tonne of Oil equivalent}} \quad 3.37$$

$$= 2.86634 \times 10^{15} \text{ Btu}$$

Convert **$2.86634 \times 10^{15} \text{ Btu to kWh}$**

1 kilowatt-hour = 3412 **Btu**,

Therefore, **$(2.86634 \times 10^{15}) \text{ Btu}$**

$$= \frac{(2.86634 \times 10^{15}) \text{ Btu} \times 1 \text{ kWh}}{3412 \text{ Btu}} \quad 3.38$$

$$= 8.400762016 \times 10^{11} \text{ kWh}$$

Electricity generated from natural gas in 2011 in the United Kingdom

$$= 8.400762016 \times 10^{11} \text{ kWh}$$

3.7.1.2 Diesel Fuel

1 Tonne of Diesel Oil = 7.5 Barrels

Therefore, 71.6 Million Tonnes

$$= \frac{(71.6 \times 10^6) \text{ Tonnes} \times 7.5 \text{ Barrels}}{1 \text{ Tonne}} \quad 3.39$$

$$= 537000000 \text{ Barrels}$$

1 barrel of distillate oil (Diesel oil) = 5,825,000 **Btu Map Royalty Inc. (2008)**

Therefore, **$(537 \times 10^6) \text{ barrels}$** will be

$$= \frac{(537 \times 10^6) \text{ barrels} \times 5,825,000 \text{ Btu}}{1 \text{ barrel}} \quad 3.40$$

$$= 3.128025 \times 10^{15} \text{ Btu}$$

Convert **$3.128025 \times 10^{15} \text{ Btu to kWh}$**

1 kilowatt-hour = 3412 **Btu**

Therefore, **$(3.128025 \times 10^{15}) \text{ Btu}$**

$$= \frac{(3.128025 \times 10^{15}) \text{ Btu} \times 1 \text{ kWh}}{3412 \text{ Btu}} \quad 3.41$$

$$= 9.167716882 \times 10^{11} \text{ kWh}$$

Electricity generated from Diesel Oil in 2011 in the United Kingdom
 $= 9.167716882 \times 10^{11} \text{ kWh}$

3.7.1.4 Anthracite Coal

1 Tonne of Oil equivalent (Toe) = 1.5 Tonnes of Hard Coal

Therefore, **30.8 Million Tonnes of Oil equivalent**

$$= \frac{(30.8 \times 10^6) \text{ Tonnes of Oil equivalent} \times 1.5 \text{ Tonnes}}{1 \text{ Tonnes of Oil equivalent}} \quad 3.42$$

$$= 46200000 \text{ Tonnes}$$

1 metric Tonne of Coal = 22,877,388 **Btu Ag Decision Maker (2008)**

Therefore, $(46.2 \times 10^6) \text{ Tonnes}$ will be

$$= \frac{(46.2 \times 10^6) \text{ Tonnes} \times 22,877,388 \text{ Btu}}{1 \text{ Tonne}} \quad 3.43$$

$$= 1.056935326 \times 10^{15} \text{ Btu}$$

Convert **$1.056935326 \times 10^{15} \text{ Btu}$ to kWh**

1 kilowatt-hour = 3412 **Btu**,

Therefore, **$(1.056935326 \times 10^{15}) \text{ Btu}$**

$$= \frac{(1.056935326 \times 10^{15}) \text{ Btu} \times 1 \text{ kWh}}{3412 \text{ Btu}} \quad 3.44$$

$$= 3.097700251 \times 10^{11} \text{ kWh}$$

Electricity generated from Standard Anthracite Coal in 2011 in the United Kingdom
 $= 3.097700251 \times 10^{11} \text{ kWh}$

Total Electricity Generated in 2011 in the United Kingdom from the natural gas, oil and coal
 $= 8.400762016 \times 10^{11} \text{ kWh} + 9.167716882 \times 10^{11} \text{ kWh} + 3.097700251 \times 10^{11} \text{ kWh}$

$$= 2.066617915 \times 10^{12} \text{ kWh}$$

Therefore,

Total Electricity Generated in 2011 in the United Kingdom from the natural gas, oil and coal

$$= 2.066617915 \times 10^{12} \text{ kWh}$$

3.8 DETERMINE ELECTRICITY CONSUMED PER CAPITA IN EACH COUNTRY BASED ON THE POPULATION AS STATED BY WORLD BANK.

The United Kingdom population data compiled by **World Bank (2012)** would be used in this analysis. Further analysis on the effect of population growth or decline will be made in the next chapter for the 28 considered countries.

Table 9 shows the population data of the United Kingdom from the year 2011.

Table 9: United Kingdom Population 1990-2011 World Bank (2012)

Country	Year	Population	Electricity consumed per population (kWh per capita)
United Kingdom	2011	62,641,000	329914.5791

3.8.1 Sample Calculations

Electricity consumed per population is calculated thus:

$$\text{Electricity consumed} = \frac{\text{Total electricity consumed in 2011}}{\text{population in 2011}} \quad 3.45$$

$$= \frac{2.066617915 \times 10^{12}}{6264100} \text{ kWh per capita} \quad 3.46$$

$$= 329914.5791 \text{ kWh per capita}$$

Therefore, electricity consumed per capita in the United Kingdom in 2011

$$= 329914.5791 \text{ kWh per capita}$$

3.9 DETERMINE THE CARBON DIOXIDE EQUIVALENTS (GHG) OF THE DIFFERENT FOSSIL FUELS USING CARBON TRUST CONVERSIONS

The Carbon Trust (2011) energy conversion factors given in Table 4 will be used to determine the carbon dioxide equivalent emissions from the fossil fuels used in the electricity generation.

3.9.1 Natural Gas

Electricity generated from natural gas in 2011 in the United Kingdom

$$= 8.400762016 \times 10^{11} \text{ kWh}$$

Using the carbon trust conversion factor for natural gas, we can convert *kWh* to *kgCO₂ e*.

$$1 \text{ kWh} = 0.1836 \text{ kgCO}_2 \text{ e}$$

Therefore,

$$= \frac{(8.400762016 \times 10^{11}) \text{ kWh} \times 0.1836 \text{ kgCO}_2 \text{ e}}{1 \text{ kWh}} \quad 3.47$$

$$\text{Natural gas} = 1.542379906 \times 10^{11} \text{ kgCO}_2 \text{ e}$$

3.9.2 Diesel Oil

Electricity generated from diesel oil in 2011 in the United Kingdom

$$= 9.167716882 \times 10^{11} \text{ kWh}$$

Using the carbon trust conversion factor for natural gas, we can convert *kWh* to *kgCO₂ e*.

$$1 \text{ kWh} = 0.2517 \text{ kgCO}_2 \text{ e}$$

Therefore,

$$= \frac{(9.167716882 \times 10^{11}) \text{ kWh} \times 0.2517 \text{ kgCO}_2 \text{ e}}{1 \text{ kWh}} \quad 3.48$$

$$\text{Diesel Fuel} = 2.307514339 \times 10^{11} \text{ kgCO}_2 \text{ e}$$

3.9.3 Anthracite Coal

Electricity generated from Anthracite Coal in 2011 in the United Kingdom

$$= 3.097700251 \times 10^{11} \text{ kWh}$$

Using the carbon trust conversion factor for Anthracite Coal, we can convert kWh to $kgCO_2 e$.

$$1 kWh = 0.3325 kgCO_2 e$$

Therefore,

$$= \frac{(3.097700251 \times 10^{11}) kWh \times 0.3325 kgCO_2 e}{1 kWh} \quad 3.49$$

$$\textbf{Standard Anthracite Coal} = 1.029985333 \times 10^{11} kgCO_2 e$$

3.10 COMPARE RESULTS WITH UNFCCC BASE YEAR NATIONAL EMISSION LEVEL

According to section 1.2, carbon credits are defined as financial tradable incentives equal to one metric tonne of greenhouse gas (GHG) emissions based on carbon dioxide (CO₂) equivalent permanently removed or prevented from being emitted to the atmosphere.

From calculated values in section 3.9,

Natural Gas utilized by the United Kingdom for electricity generation in 2011 produced

$$\textbf{Natural Gas} = 1.542379906 \times 10^{11} kgCO_2 e$$

Diesel Fuel utilized by the United Kingdom for electricity generation in 2011 produced

$$\textbf{Diesel Fuel} = 2.307514339 \times 10^{11} kgCO_2 e$$

Standard Anthracite Coal utilized by the United Kingdom for electricity generation in 2011 produced

$$\textbf{Standard Anthracite Coal} = 1.029985333 \times 10^{11} kgCO_2 e$$

Total $kgCO_2 e$ emissions produced in the United Kingdom in 2011 will be,

$$= 1.542379906 \times 10^{11} kgCO_2 e + 2.307514339 \times 10^{11} kgCO_2 e + 1.029985333 \times 10^{11} kgCO_2 e$$

$$= 4.947508629 \times 10^{11} kgCO_2 e$$

But,

1 metric tonne = 1000kg

Therefore,

$4.947508629 \times 10^{11}$ kgCO₂ e will yield,

$$= \frac{4.947508629 \times 10^{11} \text{ kgCO}_2 e \times 1 \text{ Tonne}}{1000 \text{ kg}} \quad 3.50$$

$$= \mathbf{494750862.9 \text{ TCO}_2 e}$$

From Table 5, the 1990 UNFCCC base year national emission level for the United Kingdom

$$= \mathbf{779904144 \text{ TCO}_2 e}$$

Then, % deviation of emissions in $\text{TCO}_2 e$

$$= 100 - \left(\frac{494750862.9 \text{ TCO}_2 e}{779904144 \text{ TCO}_2 e} \times 100 \right) \% \quad 3.51$$

$$= \mathbf{37\%}$$

Therefore, comparing 1990 and 2011, GHG carbon dioxide equivalent emissions decreased by 37%. This means that the United Kingdom met the Kyoto Protocol target for 2011 with a deviation of more than 5% a year from 2008-2012 compared to their emissions in 1990 as stated in section 1.2 .

Table 10 shows the comparism and % deviation in Tonnes of carbon dioxide equivalent between 1990 and 2011

Table 10: Percentage (%) deviation of calculated tonnes of carbon dioxide equivalent from the 1990 UNFCCC base year national emission level.

Country	1990 UNFCCC Base year level of $\text{TCO}_2 e$	2011 Calculated $\text{TCO}_2 e$	% deviation of $\text{TCO}_2 e$
United Kingdom	779904144.0	494750862.9	37

3.11 DETERMINATION OF THE CARBON CREDITS

To determine the total carbon credits earned or required to offset GHG emissions, the assigned amount units issued by the United Nations in Figure 13 is utilized.

1 metric tonne of carbon dioxide equivalents emissions ($TCO_2 e$) = 1 carbon credit

Carbon dioxide equivalent reduced = carbon credit earned

Using the sample formulae in section 3.9 and equation 3.51, the $TCO_2 e$ generated from 2008 to 2010 is given thus:

$$2008 = 550619226.5 \text{ } TCO_2 e$$

$$2009 = 506392369.1 \text{ } TCO_2 e$$

$$2010 = 597310532.8 \text{ } TCO_2 e$$

$$2011 = 494750862.9 \text{ } TCO_2 e$$

Total $TCO_2 e$ for (2008 – 2011) years

$$= 550619226.5 + 506392369.1 + 597310532.8 + 494750862.9$$

$$= \mathbf{2149072991} \text{ } TCO_2 e$$

Then,

Carbon credit earned by the United Kingdom in 2011 will be,

(Assigned Amount Units issued by the United Nations) - (Total $TCO_2 e$ for 2008 -2011) years

$$= (3,412,080,630 - 2149072991) \text{ } TCO_2 e$$

$$= \mathbf{1263007639} \text{ } TCO_2 e$$

1 metric tonne of carbon dioxide equivalent equals 1 Assigned Amount Unit and also equals 1 carbon credit.

Therefore, the amount of carbon credits earned by the United Kingdom in 2011 from the allocated Assigned Amounts Units issued by the United Nations

$$= \mathbf{1,263,007,639} \text{ } \textit{carbon credits}$$

3.12 CHAPTER SUMMARY

The governing combustion equation showed that coal emitted more carbon dioxide emission than natural gas or oil. The methodology analysed three case studies with regards to the Annex I and Parties to the Annex I and the EIT countries. The electricity generated using the statistical world data compiled by British Petroleum in June 2012, was further analysed based on the emission factors of each country from 1990-2011 Defra/DECC (2012) in order to determine the TCO₂e emitted by each country. The carbon credits were generated with respect to the assigned amounts issued by the United Nations and the CO₂e emissions from each country.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The results derived in determining the carbon credits are based on the carbon dioxide equivalent emission from the electricity generated in 28 countries. The data utilized for this analysis was from the British Petroleum World Statistical Review Data compiled in June 2012.

The first phase of this chapter concentrates on the results generated in the three case studies of the methodology that show the demand level of the different fossil fuels in the energy mix for the 28 considered countries from 1990-2011. Electricity generated from 1990-2011 will be derived from the energy mix and the tonnes of carbon dioxide equivalent (CO₂e) emitted by each country from 1990-2011 will be compared to the population census for each country also from 1990-2011.

Comparing the electricity to the population will yield the electricity consumed per person in each country which decodes the carbon dioxide equivalent (CO₂e) emissions emitted per person.

The second stage in this chapter would centre on the discussions of the results. The discussions would argue the following points including:

1. The effect of population increase on the electricity generated and the CO₂e emission increase or decrease in both Annex I and Parties to the Annex I and EIT countries with regards to the increased shift to renewable sources of energy, energy efficiency and carbon capture and sequestration.
2. The trends of CO₂e emissions from 1990-2011.
3. CO₂e emission effect on the optimization of the voluntary carbon market and its credits.

4.2 RESULTS

The methodology presented three case studies including:

1. Case Study 1: The CO₂ emission baseline set by the UNFCCC.
2. Case Study 2: The Kyoto Protocol commitment period for Annex I and Parties to Annex I countries.
3. Case Study 3: Non Kyoto Protocol ratified Annex I countries and EIT countries.

4.2.1 CASE STUDY 1

The emission baselines or base year levels set by the UNFCCC for each country is shown in Figure 14. This indicates the limit of GHG emissions to which all countries that have ratified the Kyoto Protocol (Annex I and Parties to the Annex I) must adhere to as long as they remain legally bound to the Kyoto Protocol.

From Figure 14, it can be deduced that the first four countries with the highest GHG emitting limits are: the Russian Federation, which has the highest base year level of 3,323,419,064 TCO₂e (Tonnes of carbon dioxide equivalent) followed by a close range between Japan and Germany with 1,216,331,418 TCO₂e and 1,232,429,543 TCO₂e respectively and the United Kingdom with 779,904,144 TCO₂e. The country with the least UNFCCC base year level is Switzerland with an emission limit of 52,790,957 TCO₂e.

The Russian Federation which was dissolved from the Soviet Union in 1991 is a peculiar case as its UNFCCC base year level was set in 1990 when it was still part of the Soviet Union and as a result acquired surplus emitting rights. This is reflected in its high UNFCCC base year level of emissions in Figure 14. The values of the UNFCCC base year levels of the considered Annex I and Parties to the Annex I is given in Table 5 refer chapter 3.

UNFCCC BASE YEAR LEVEL (TCO₂e) vs. ANNEX I and PARTIES to the ANNEX I

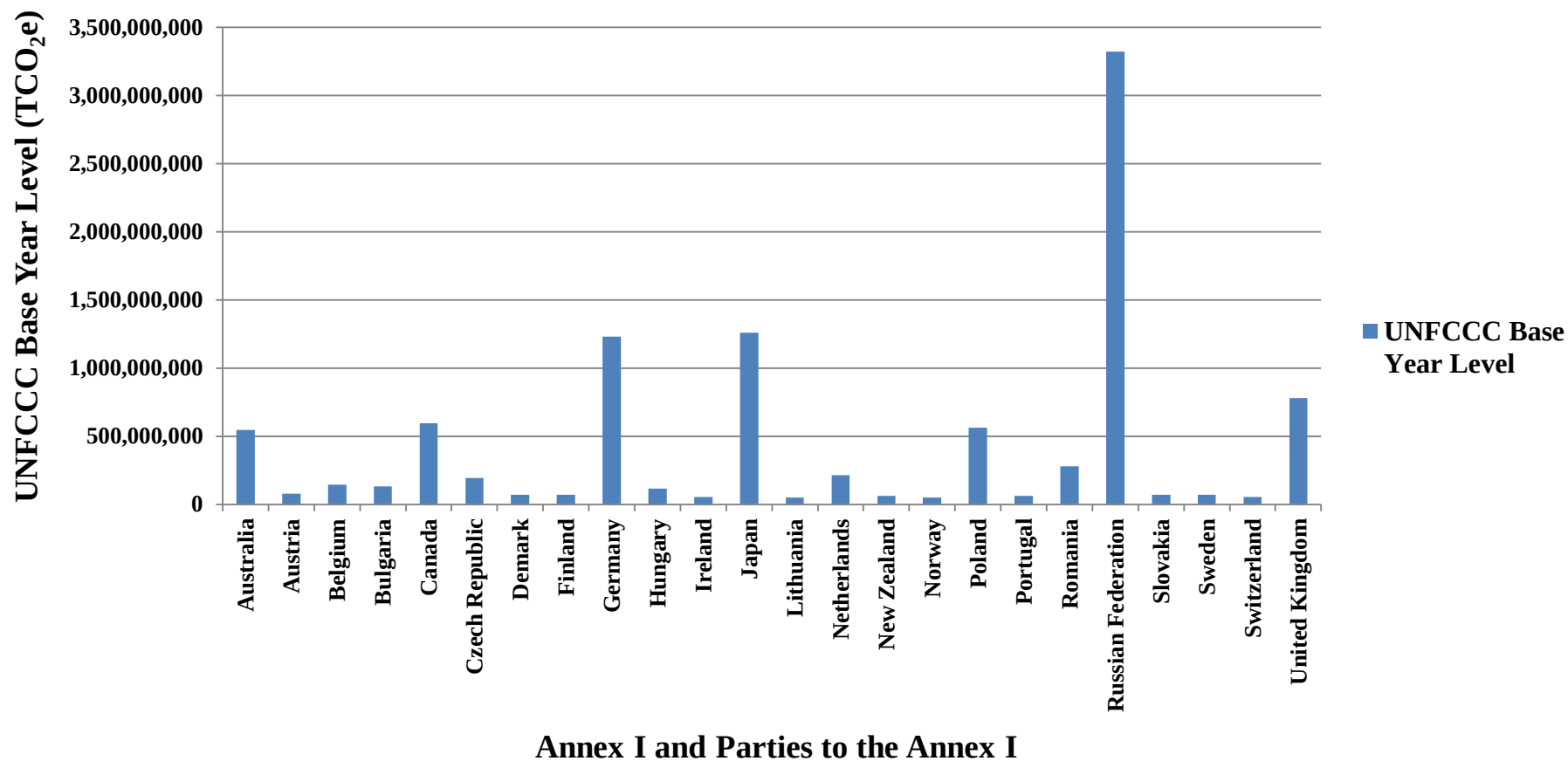


Figure 14: UNFCCC Base Year Level vs. Annex I and Parties to the Annex I

Figure 15 shows the electricity generated in Terawatt-hour (TWh) for the considered Annex I and Parties to the Annex I. It indicates that the level of electricity generated in their UNFCCC base years was a major contributing factor to the GHG emissions and therefore the UNFCCC base year level was set giving high priority to the electricity generated.

The Russian Federation formally the Soviet Union generated the highest electricity with value (9.01033×10^{12} kWh or 9.01 TWh to the nearest 2 decimal place) followed by Japan (4.44481×10^{12} kWh or 4.44 TWh), Germany (3.56026×10^{12} kWh or 3.56 TWh) and United Kingdom (2.40649×10^{12} kWh or 2.14 TWh). The electricity generated values for the base years are given in Table 18 refer Appendix C.

Electricity Generated (TWh) in the Base Year of each Annex 1 Country and Parties to the Annex 1

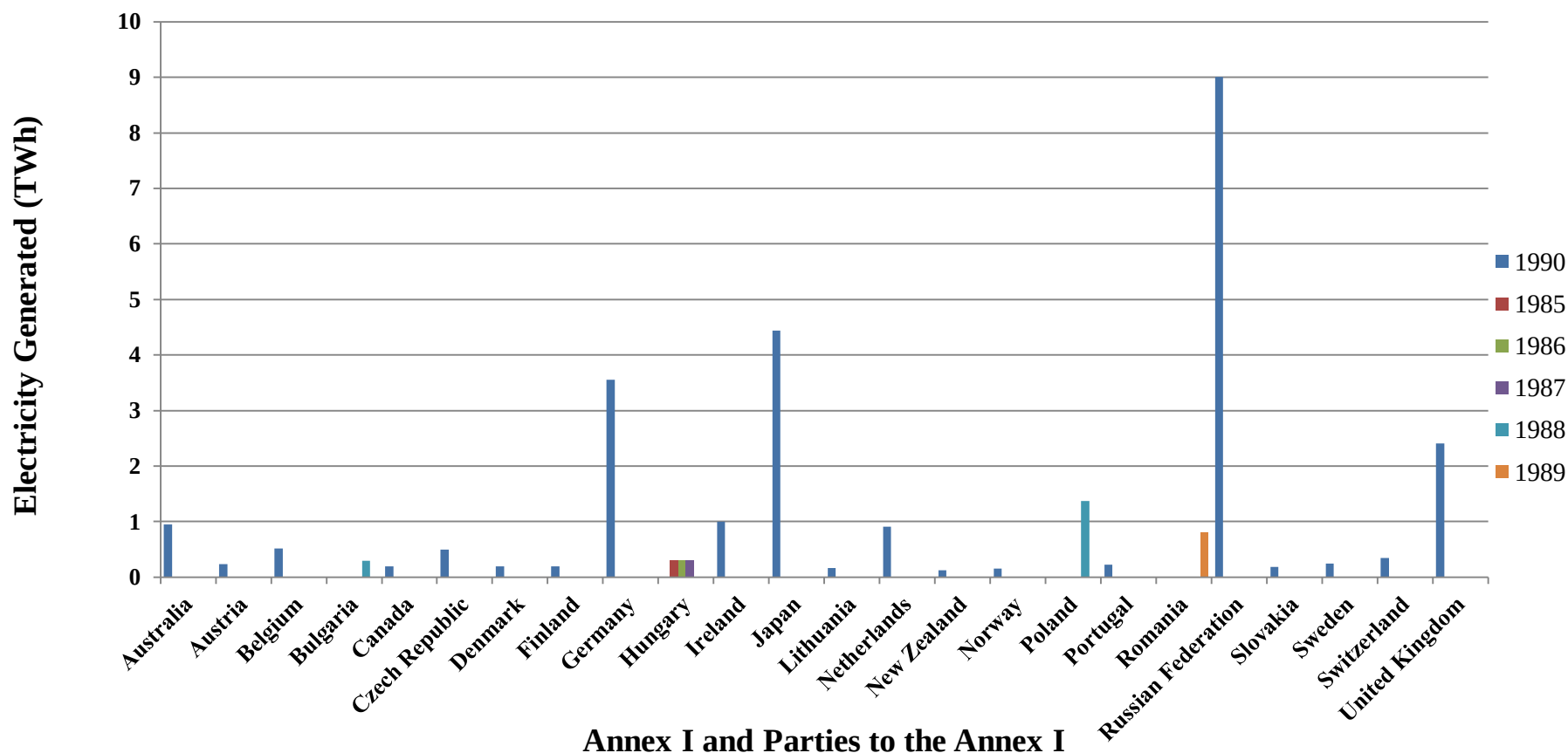


Figure 15: Electricity Generated (TWh) in the base year of each considered Annex I country and Parties to the Annex I

4.2.2 CASE STUDY 2

The Kyoto Protocol first commitment period for Annex I and Parties to Annex I countries is from 2008- 2012. Within these years, the total CO₂e emissions produced from the Kyoto Protocol ratified countries must not exceed their UNFCCC base year level otherwise they would be required to purchase carbon credits to offset their excess CO₂e emissions.

The British Petroleum statistical review fuel consumption data used in this analysis present information on the fossil fuels used for electricity generation from 2008-2011. Therefore, analysis is made based on these years.

As noted in section 4.2.1, the electricity generated by different countries is a major source of CO₂e emissions. Figure 16 shows the electricity generated in the Kyoto Protocol commitment period (2008-2011) and in the UNFCCC base year of 1990 for the considered Annex I and Parties to the Annex I. All other Annex I and Parties to the Annex I have their base year as 1990 except Bulgaria, Hungary, Poland and Romania. Also, Figure 16 on a scale of 1:5 shows that the Russia Federation still accounts for the highest electricity generated amongst the Annex I countries and Parties to the Annex 1. Following Russia, the electricity generated in the other countries in a decreasing order takes the form: Japan, Germany, United Kingdom, Canada, Poland, Australia, Netherlands etc. Details of the electricity generated data from 2008-2011 is given in Table 19 refer Appendix C.

Figure 16 also indicates a reduction in electricity generated in Russia by 21.2% in the year 2011 (7.1 TWh) compared to their 1990 electricity of (9.01 TWh). Japan on the other hand increased their electricity generated in 2011 (4.87 TWh) slightly above their 1990 (4.44 TWh) level with a percentage of 8.8%. Germany like Russia also reduced their electricity from 1990 (3.56 TWh) to 2011 (2.97 TWh) by 16.6%. Electricity reduction in the Russian Federation and Germany is mainly due to the reduction and shift in the utilization of oil and coal in electricity generation to natural gas. While Japan relied more on coal and natural gas for its electricity generation leading to an 8.8% increase. Following the UNFCCC base year 1990, the total electricity generated by Canada from 2008-2011 was 14.5% more than that generated by United Kingdom within 2008-2011.

Figure 17 shows the CO₂e emissions from the electricity/heat generated. From figure 16, Australia and Poland that generated less electricity than the United Kingdom and Canada is shown to emit higher TCO₂e in Figure 17. The reason is that the energy mix demand for the United Kingdom and Canada utilizes more natural gas and oil than coal and therefore emit

less TCO_{2e}. On the other hand, Poland and Australia's energy mix demand utilizes more coal than natural gas and oil. Coal is a high carbon emitting fossil fuel and therefore its high utilization is reflected in TCO_{2e} emitted by Poland and Australia. From Table 12, 13 and 14 refer Appendix B, it can be deduced that these countries total energy mix consumption increased from 2008 - 2011 as follows:

1. Poland: Coal (58.6%), Oil (27.1%) and Natural gas (14.2%).
2. Australia: Coal (43.3%), Oil (37.1%) and Natural gas (19.6%).
3. United Kingdom: Coal (17.1%), Oil (38.0%) and Natural gas (42.9%).
4. Canada: Coal (11.7%), Oil (47.25%) and Natural gas (41.0%).

Also, according to **Defra/DECC (2012)**, the emission factor values for Poland and Australia are higher than those for the United Kingdom and Canada as indicated in Figure 10 and 11 refer chapter 3.

Electricity Generated (TWh) from (2008-2011) and in the UNFCCC base years vs. Annex I and Parties to the Annex I

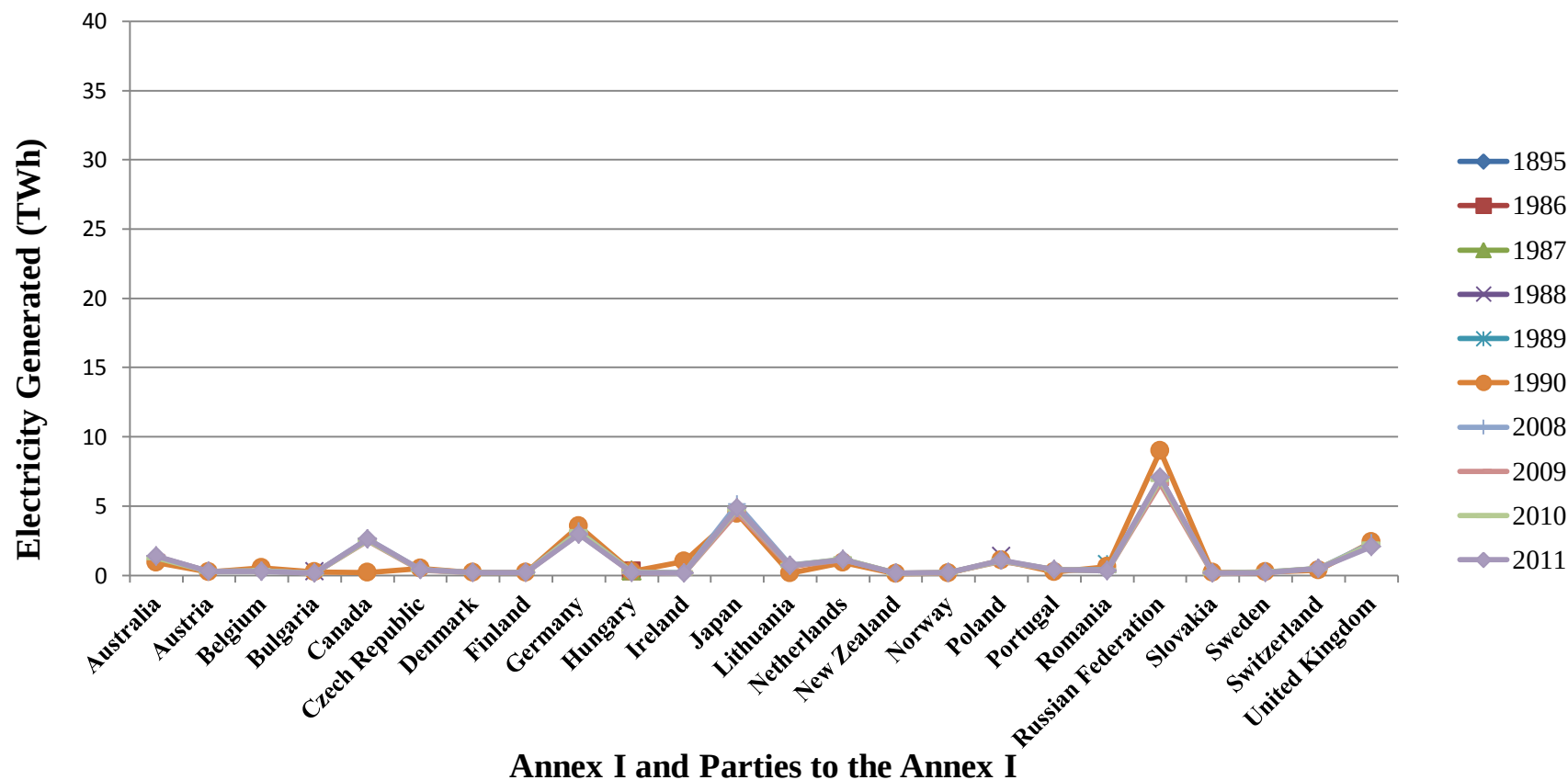


Figure 16: Electricity generated in the Kyoto Protocol commitment period (2008-2011) and in the UNFCCC base year for the considered Annex I and Parties to the Annex I.

Million Tonnes of CO₂e vs. Annex I and Parties to the Annex I

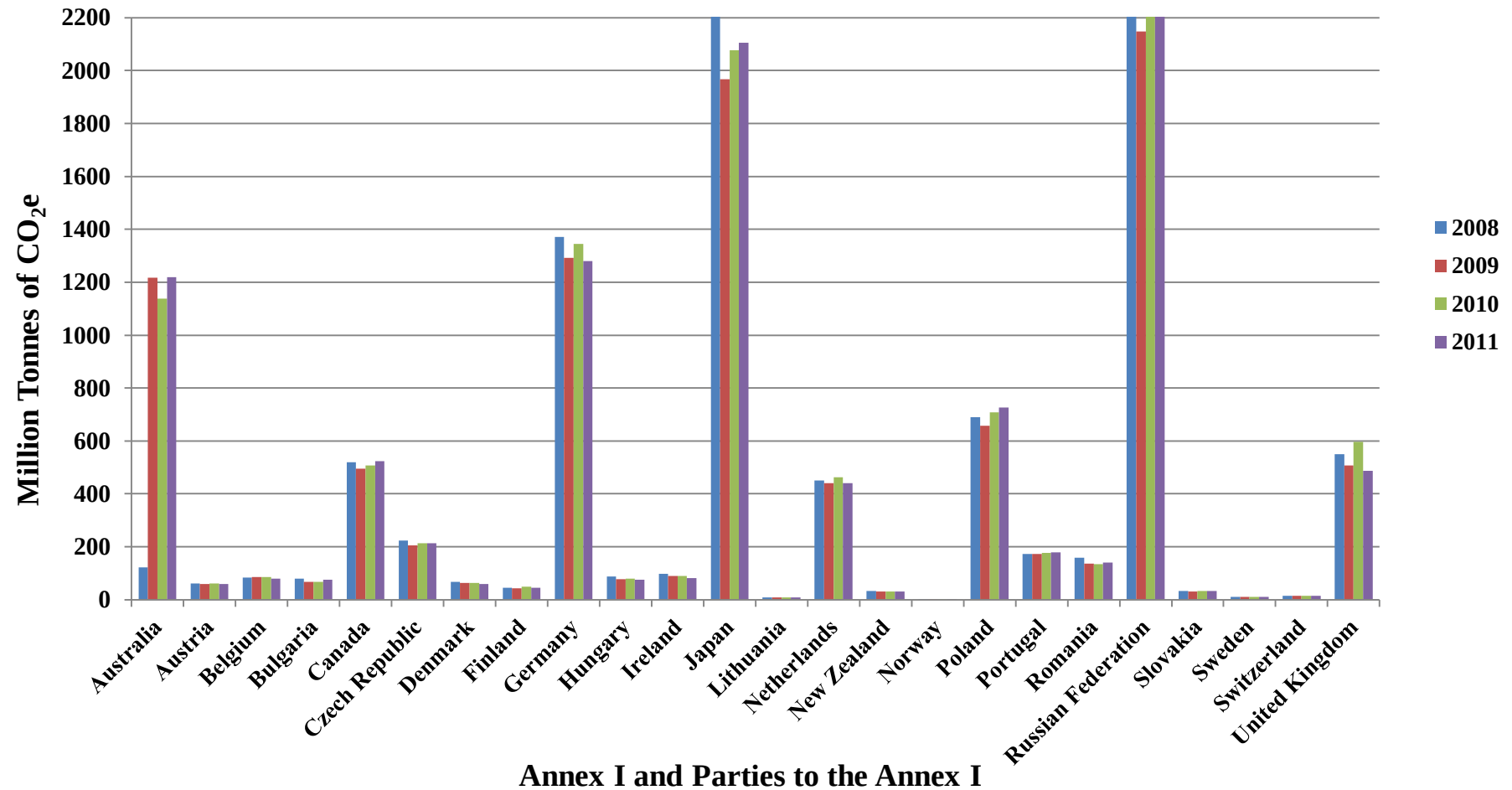


Figure 17: Million Tonnes of CO₂e vs. Annex I and Parties to the Annex I

The carbon credits generated based on the total TCO₂e emitted from the electricity generated (2008-2011) in the Annex I and Parties to the Annex I is shown in Figure 18. The negative amounts indicated the carbon credits needed to offset the excess CO₂e emitted by the nations while the positive values indicated the carbon credits earned from the assigned amounts issued by the United Nations.

From Figure 18, Germany, Netherlands, Ireland, Japan, Portugal and Poland will require carbon credits of 420,213,210, 792,067,875, 41,878,62, 2,431,284,956, 318,559,817 and 132,650,524 respectively to offset their excess CO₂e emission.

The remaining countries have successfully reduced their CO₂e emissions and therefore earned carbon credits. Table 20 gives details of the carbon credit values.

Note that the Assigned Amount Units for Australia was not provided in the data source **UNFCCC (2008)**.

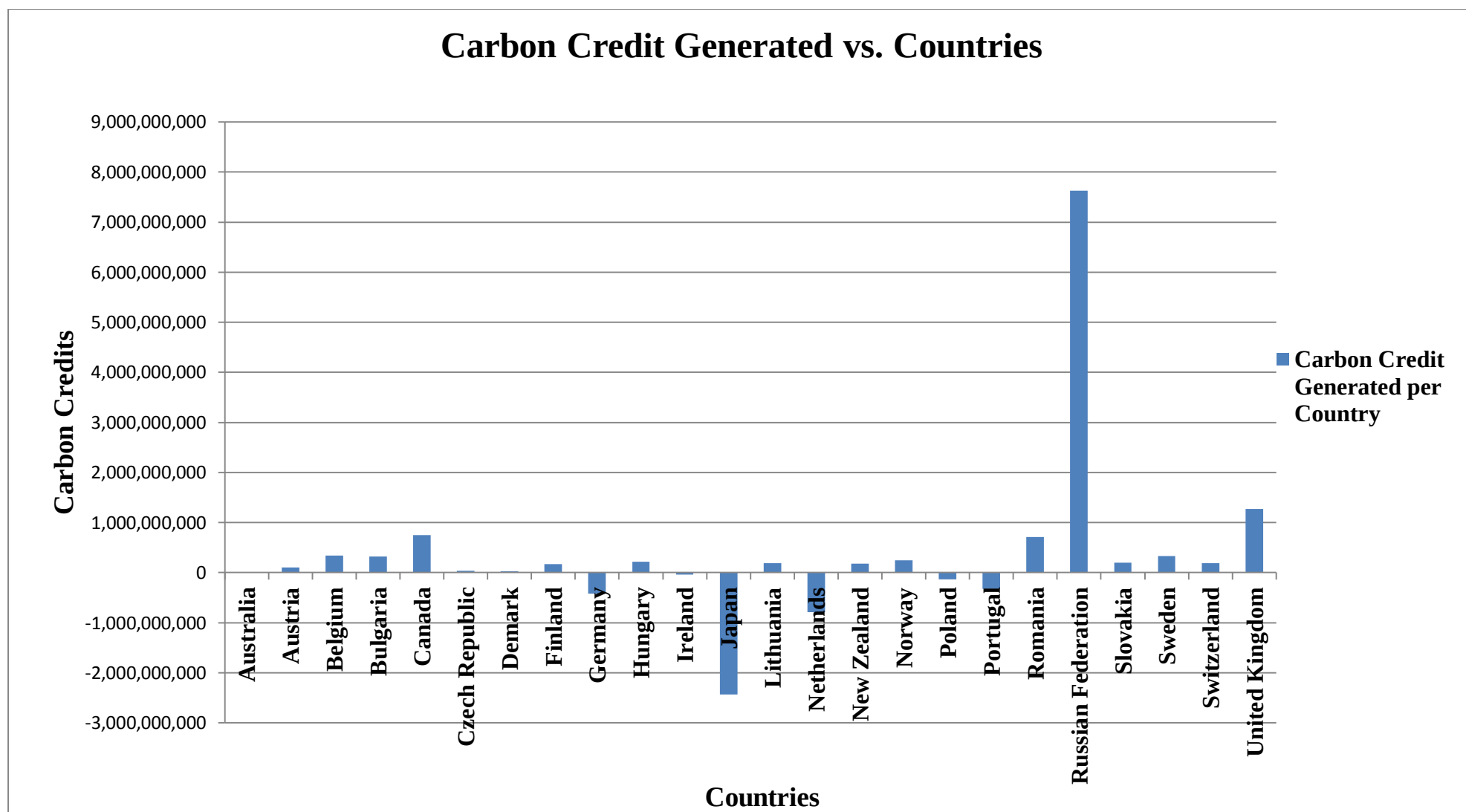


Figure 18: Carbon Credits generated vs. Countries

4.2.3 CASE STUDY 3

The EIT (Economies in Transition) and non-ratified Kyoto Protocol countries of main focus in this section are the United States of America, China, India and South Africa. The energy mix demand in their generated electricity is shown in Figure 19. The resulting TCO_{2e} are also shown in Figure 20.

Figure 19 and 20 are produced with the data from all the considered countries but preference would be given to the EIT countries in the explanation.

Figure 19 show that China generates the highest electricity with a steady increasing value of 11.1 TWh (1.1123×10^{13} kWh) in 2002 and 25.7 TWh (2.5781×10^{13} kWh) in 2011. This is due to the economic growth of China and the many manufacturing industries and infrastructural boost.

The United States in second place, experienced a reduction in power generated by 8.47% from 24.4 TWh (2.44017×10^{13} kWh) in 2007 to 22.5 TWh (2.25249×10^{13} kWh) in 2009, an increase to 23.3 TWh (2.3285×10^{13} kWh) in 2010 and a further decrease by 1.2% to 23 TWh (2.30051×10^{13} kWh) in 2011. The United States 'Cap and Trade' system in reducing it carbon emission has contributed to their 2011 electricity reduction as well as investments in carbon capture and sequestration from coal power plants.

India follows with a steady increase of 56% in electricity generation from 2.51 TWh (2.50608×10^{12} kWh) in 1995 to 5.69 TWh (5.69043×10^{12} kWh) in 2011. South Africa also shows a steady increase of 29.7% in electricity generation from 0.92 TWh (9.24191×10^{11} kWh) in 1994 to 1.31 TWh (1.31402×10^{12} kWh) in 2011.

Figure 20 also indicates that China emits the highest level of TCO_{2e} with a value of (2.0×10^{10} TCO_{2e}). The United States follows as the second highest emitter with its highest value of (1.45×10^{10} TCO_{2e}) in 2002 and an emission decline in 2011 with value (1.27×10^{10} TCO_{2e}).

Further, the third highest CO_{2e} emitter India shows steady emission increase from 1992 with value (1.82×10^9 TCO_{2e}) to 2011 with (5.36×10^9 TCO_{2e}).

South Africa also experienced a steady emission increase from 2008 with value (1.11×10^9 TCO_{2e}) to 2011 with value (1.0×10^9 TCO_{2e}).

Total Electricity Generated (kWh) vs. Year

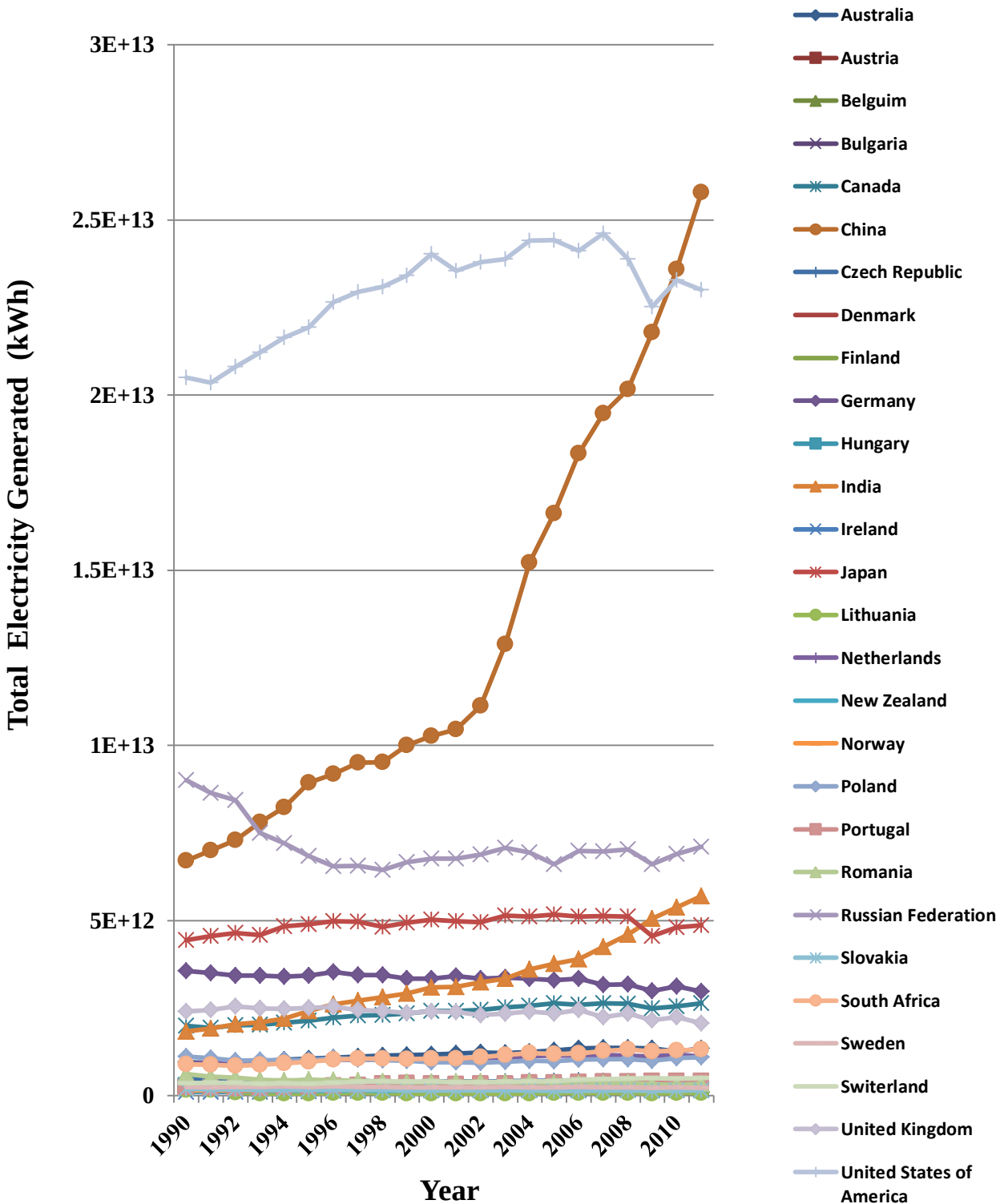


Figure 19: Total Electricity generated (kWh) vs. Year (with particular interest in the EIT and non-ratified Kyoto Protocol Countries).

Total Tonnes of CO₂e Emissions Per Year vs Countries

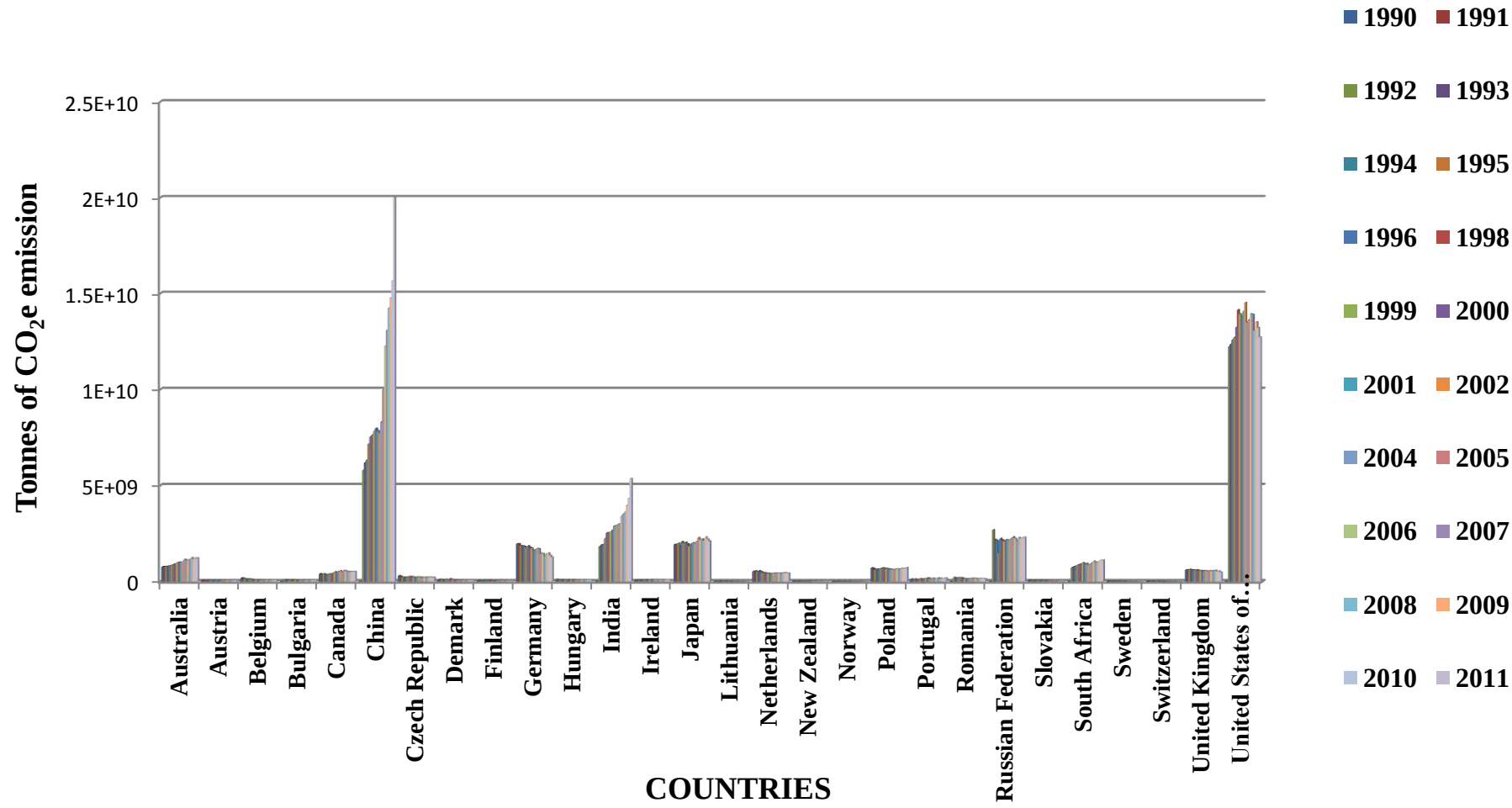


Figure 20: Total Tonnes of CO₂e per year vs. Countries

4.3 DISCUSSIONS

4.3.1 THE EFFECT OF POPULATION ON ELECTRICITY GENERATED

The effect of population on the electricity generated is given in Figure 21. The figure indicates that Annex I countries and Parties to the Annex I consume the highest amount of electricity than the EIT countries. Less electricity is consumed per person in EIT countries like China and India due to their growing population even though they are shown to generate high levels of electricity refer Figure 19. Table 15, 16 and 17 shows the ever increasing rate of China and India's population.

The idea that an increase in population results to an increase in the energy consumed may not be entirely true for developed, developing and EIT countries. Figure 21 shows that the Annex I countries and parties to the Annex I with less population consumes more electricity than the developing or EIT countries in the world. The reason remains that the high degree of industrialization and the standard of living of the developed countries requires greater electricity consumption than developing and EIT countries that still experience high poverty levels and in many areas especially the rural communities' access to electricity or the basic needs of life is limited. Secondly, with the instability of oil and gas prices developed countries that require huge amounts of electricity have been forced to continue utilizing the cheap, carbon rich fossil fuel coal to meet their energy demands resulting to high CO₂e emission levels.

With the evidence of the current occurrence of climate change and increase of GHG emissions in the atmosphere, governments of developed countries (Annex I and Parties to the Annex I) and leading EIT countries (China) now invest in renewable energy sources and look to new technologies like Carbon Capture and Sequestration especially in coal-fired plants, Cap and Trade system and implementation of Carbon Taxes to create a balance between their high electricity generation using carbon rich coal and ensuring a clean, low carbon world.

The five countries indicated to have the highest levels of electricity consumption per person include

1. The United States of America with its highest electricity consumed in 2000 (85159.0 kWh per Capita) and lowest in 2009 (73425.7 kWh per Capita). In 2011, the electricity consumed per person increased by 0.55%.

2. Canada consumed its highest electricity in 2005 (81813.3 kWh per Capita), and lowest in 2009 (73827.7 kWh per Capita). In 2011, the electricity consumed per person increased by 3.44%.
3. Netherlands also consumed its highest electricity in 2007 (70993.7 kWh per Capita) and lowest in 2011.
4. Australia, the fourth country has its highest consumption of electricity in 2007 at (64420.8 kWh per Capita) and lowest within its emission target years in 2010 at (56736.8 kWh per Capita).
5. Switzerland consumed its highest electricity in 2009 (63877.0 kWh per Capita) and maintained its electricity consumption in 2010 and 2011 at (62850.5 kWh per Capita).

ELECTRICITY GENERATED PER POPULATION (kWh per Capita) vs COUNTRIES

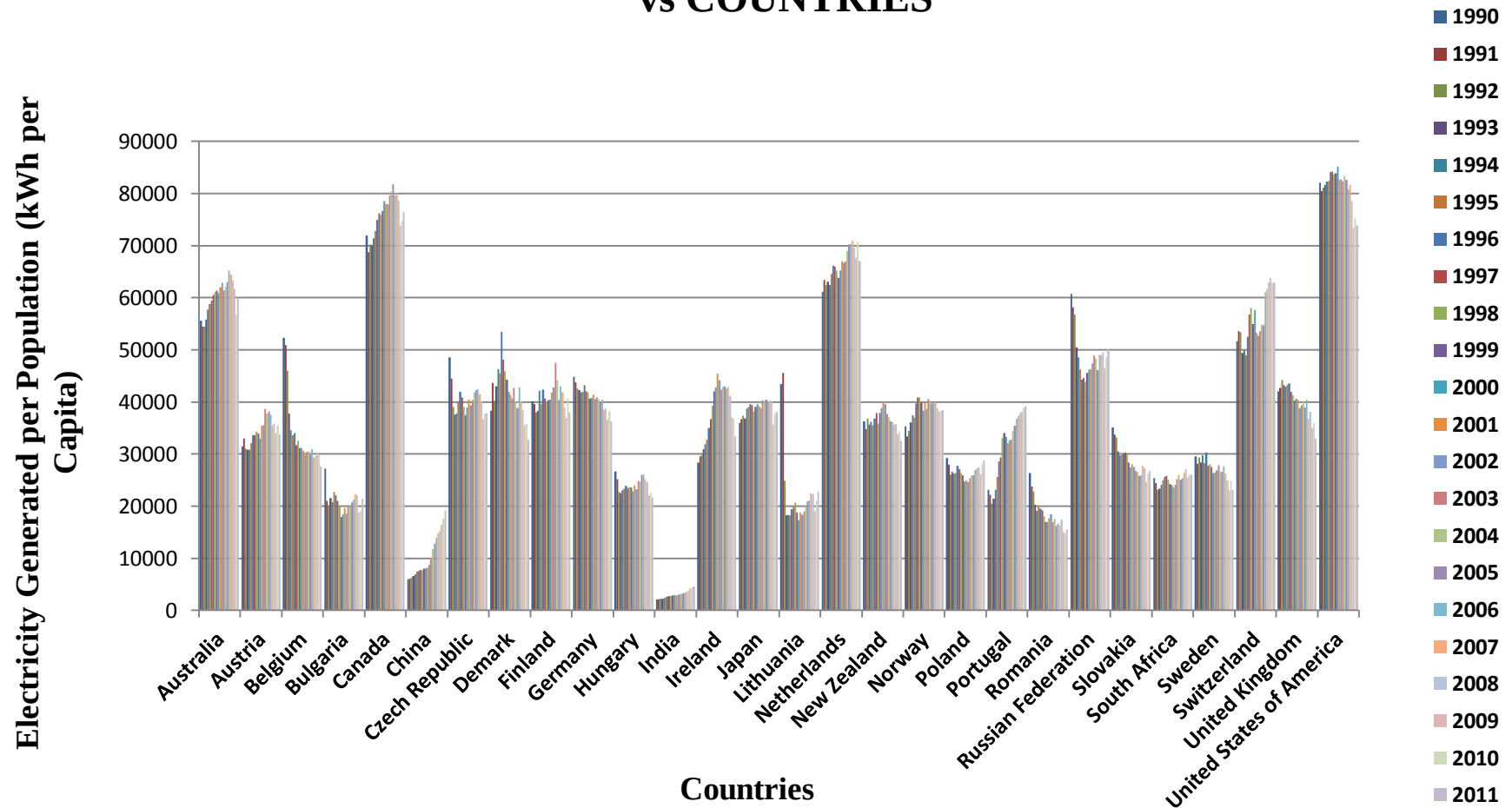


Figure 21: Electricity Generated per Population (kWh per Capita) vs. Countries

4.3.2 TRENDS OF TCO₂e EMISSIONS

The trend of the CO₂e emissions between the Annex I and Parties to the Annex I and EIT countries is shown in Figure 22.

Figure 22 indicates the Annex I and Parties to the Annex I experienced a sharp increase in TCO₂e from 1991-1992. For the EIT countries, their emission factors were not provided by **Defra/DECC (2012)** and therefore the TCO₂e produced in (1990-1991) were not recorded.

The Annex I and Parties to the Annex I have experienced an undulating effect in their TCO₂e with its lowest emission in 2009 as a result of the economic recession which led to reduced industrial activities and an overall decline in economic growth.

The EIT has shown a steady increase in TCO₂e emissions from 2001 to 2011 by 54.8%. This is due to the economic boost in the EIT countries. Another reason is that though EIT countries under the Kyoto Protocol has highly benefitted from CDM projects which should reduce their GHG emissions, most developed countries transfer manufacturing processes to EIT countries that require huge amounts of electricity generation to function. The low cost of production, closeness to raw materials, rapid return on investment and qualified labour are factors that make EIT countries an attractive choice. This has no doubt increased the economic growth of the EIT leading countries like China and India but also adversely affected the environment with steady increases of GHG emissions in the atmosphere. China for example, has a large natural resource deposit of coal and utilizing this natural resource instead of outsourcing for other fossil fuels and the fact that renewable energy options cannot guarantee 100% electricity generation to meet the high demand, continues to increase the TCO₂e emissions in the EIT's.

Trends of Tonnes of CO₂e Emissions vs. Year

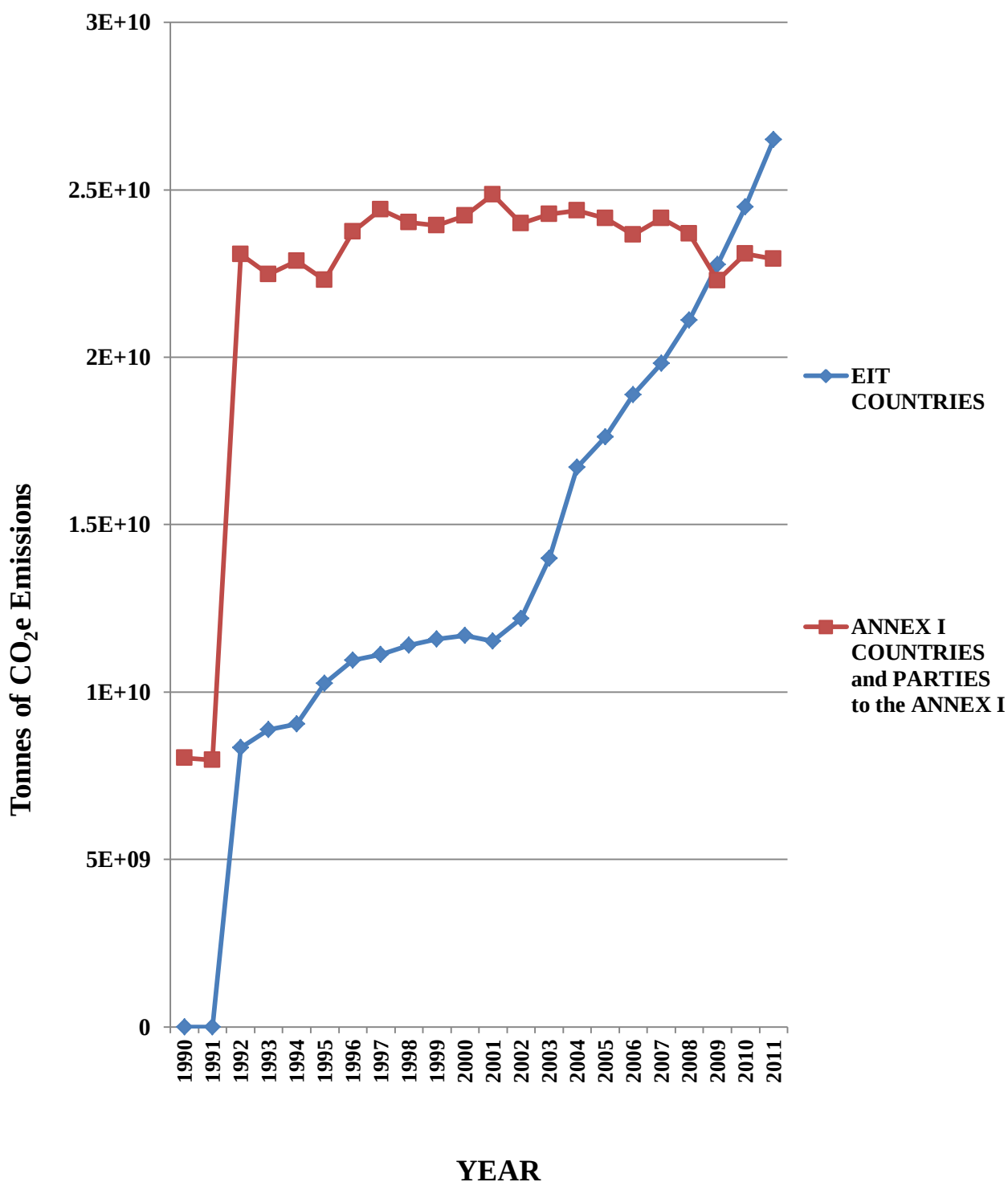


Figure 22: Trends of CO₂e emissions per year in Annex I and Parties to the Annex I and the EIT countries.

4.3.3 CO₂e EMISSION EFFECT ON THE OPTIMIZATION OF THE VOLUNTARY CARBON MARKET AND ITS CREDITS.

With the first commitment phase of Kyoto Protocol ending in December 2012, it is most likely that the carbon market focused on the carbon credits generated from the reduction or excess CO₂e emissions would shift from the compliance carbon market to the voluntary carbon market and its credits. Also, with the resignation of Canada from the Kyoto Protocol effective from December 2012 which is supported by Japan and Germany and the continued reluctance of the United States of America to ratify the Kyoto protocol even though they remain the second highest CO₂e emitting country, it seems that the world G8 leading countries has lost total confidence in the Kyoto Protocol and the compliance market it operates. Another reason is that EIT countries like China and India experiencing economic boost have also become the first and third largest CO₂e emitters in the World respectively refer Figure 20 but still are not legally bound to emission targets set by the Kyoto Protocol.

Therefore, the voluntary carbon market and its credits emerge as the fulcrum on which the global carbon market will exist in the future. The burning question remains ‘how to optimize the voluntary carbon credit in a fragmented world’.

The optimization of the voluntary carbon market and its credits will be answered and shaped by new and improved standards, utilizing voluntary carbon standards as a design plan for the future compliance market, enhanced market service providers including registries and exchanges in Europe and China, new sectors like Reducing Emissions from Deforestation in Developing Countries (REDD) and an increasing interest from companies to demonstrate corporate social responsibility through carbon- neutral initiatives. According to **Dinesh Badu (2011)** recent contributions by the EIT leading countries to promote a voluntary carbon market has seen the launch of strategic domestic initiatives to increase the voluntary credit demand, modify supplies, construct technical infrastructures and build unique standard for the thriving of the voluntary carbon market. China has set up a voluntary standard, a provincial pilot cap and trade and provincial environmental and emission exchanges, Brazil also established a state level subnational environmental registry for multiple energy and environmental assets. India another EIT country has launched its Perform, Achieve and Trade (PAT) scheme and renewable energy certificate (RECs) trading scheme that enables trading of energy- efficient certificate. For developing countries, Kenya forestry project financed by REDD has continued to yield Verified Carbon Standards (VCS) based REDD credits **Dinesh Badu (2011)**.

4.4 CHAPTER SUMMARY

The main findings in this chapter are as follows:

Amongst the Annex I and Parties to the Annex I, the Russian Federation's excess emission right has encouraged its high electricity production and CO₂e emissions because it remains safe within its Kyoto Protocol emission limit. Japan and Germany also have experienced gradual reduction in emission levels.

The electricity generated per year for the 28 considered countries showed that the United States has the highest energy demand in the Annex I while China has the highest energy demand amongst the EIT countries. The latter is as a result of the economic boost in the leading EIT country.

The increasing rates of the TCO₂e and its effect on the populations show that the Annex I and Parties to the Annex I emit higher TCO₂e than the EIT countries even though their population is lesser.

The voluntary carbon market and its credits are also becoming the main focus in the generation of carbon credits for offsetting excess CO₂e emitted from Annex I and Parties to the Annex I.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

The results discussed have shown that the effect of GHG emissions on the world's climate would continue to be a determining factor for earth longevity and sustainability. To tackle this, world cooperation is needed to reduce CO₂e emissions in the energy supply national communication sector which remains the largest source of CO₂e emission. Also, investments in clean, renewable energy sources as well as carbon capture and sequestration are technologies to urgently embrace.

The main findings of the analysis include:

1. Current facts on electricity generation now show that EIT countries have surpassed the developed countries (Annex I and Parties to the Annex I) due to their growing energy demand and industrialization. This shows the developing world and Economies in Transition will become a more attractive market for fossil fuel consumption than the developed countries that are now legally bind to reducing their emission.
2. The population indicator shows that CO₂e emissions continue to increase in the developed countries with lesser population than in the EIT that accounts for huge population. Though this is true as reflected in Figure 21, future trends show a gradually movement of the EIT leading countries on the same path as the developed countries with respect to their CO₂e emissions due to the growing energy demand and birth control rates in leading EIT countries like China.
3. The trends in CO₂e emissions from the energy mix generation in the EIT and developed countries unveil the urgent need to develop a sustainable and efficient energy future requiring active participation of all countries of the world regardless of energy demand or infrastructure.
4. The voluntary carbon market will become the focus for carbon credit generation and carbon trading in the nearest future that allows individual climate change policies and flexible reduction of CO₂e emissions in developed countries and development of the domestic carbon trading markets within individual EIT countries.

5.1 RECOMENDATION

Further work should be carried out with emphasis on the following points:

1. National Communication Sectors other than the energy supply sector analysed in this research should be considered as they contribute to the amount of CO₂e emissions in the atmosphere. They include: transportation, manufacturing industries, residential, commercial/public services and agricultural/ forestry.
2. The effects of global emission analysis with the Gross Domestic Product (GDP) indicator which accounts for a share in the economic output of any country.
3. Analysis of more emerging EIT countries including Brazil and Peru.
4. Determination of the energy demand with respect to the export/import of fossil fuel from countries and the shift to other sources of energy (renewable energy).

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APPENDIX A

Table 11 contains the latest information concerning dates of signature and receipt of instruments of ratification by the Secretary-General of the United Nations, as Depositary of the Convention. The dates in the third column are those of the receipt of the instrument of ratification, acceptance (A), approval (AA), accession (a), or succession (d).

Table 11: Date of the United Nations member countries UNFCCC signatories, ratification and entry into force UNFCCC (2012)

Participants	Signature	Ratification Acceptance (A) Accession (A) Approval (AA) Succession (D)	Entry Into Force
Afghanistan	12 Jun 1992	19 Sep 2002	18 Dec 2002
Albania		3 Oct 1994 A	1 Jan 1995
Algeria	13 Jun 1992	9 Jun 1993	21 Mar 1994
Andorra		2 Mar 2011 A	31 May 2011
Angola	14 Jun 1992	17 May 2000	15 Aug 2000
Antigua And Barbuda	4 Jun 1992	2 Feb 1993	21 Mar 1994
Argentina ^x	12 Jun 1992	11 Mar 1994	9 Jun 1994
Armenia ^x	13 Jun 1992	14 May 1993 A	21 Mar 1994
Australia	4 Jun 1992	30 Dec 1992	21 Mar 1994
Austria	8 Jun 1992	28 Feb 1994	29 May 1994
Azerbaijan	12 Jun 1992	16 May 1995	14 Aug 1995
Bahamas	12 Jun 1992	29 Mar 1994	27 Jun 1994
Bahrain	8 Jun 1992	28 Dec 1994	28 Mar 1995
Bangladesh	9 Jun 1992	15 Apr 1994	14 Jul 1994
Barbados	12 Jun 1992	23 Mar 1994	21 Jun 1994
Belarus	11 Jun 1992	11 May 2000 AA	9 Aug 2000
Belgium	4 Jun 1992	16 Jan 1996	15 Apr 1996

Belize	13 Jun 1992	31 Oct 1994	29 Jan 1995
Benin	13 Jun 1992	30 Jun 1994	28 Sep 1994
Bhutan	11 Jun 1992	25 Aug 1995	23 Nov 1995
Bolivia	10 Jun 1992	3 Oct 1994	1 Jan 1995
Bosnia And Herzegovina		7 Sep 2000 A	6 Dec 2000
Botswana	12 Jun 1992	27 Jan 1994	27 Apr 1994
Brazil ^x	4 Jun 1992	28 Feb 1994	29 May 1994
Brunei Darussalam		7 Aug 2007 A	5 Dec 2007
Bulgaria	5 Jun 1992	12 May 1995	10 Aug 1995
Burkina Faso	12 Jun 1992	2 Sep 1993	21 Mar 1994
Burundi	11 Jun 1992	6 Jan 1997	7 Apr 1997
Cambodia		18 Dec 1995 A	17 Mar 1996
Cameroon	14 Jun 1992	19 Oct 1994	17 Jan 1995
Canada	12 Jun 1992	4 Dec 1992	21 Mar 1994
Cape Verde	12 Jun 1992	29 Mar 1995	27 Jun 1995
Central African Republic	13 Jun 1992	10 Mar 1995	8 Jun 1996
Chad	12 Jun 1992	7 Jun 1994	5 Sep 1994
Chile ^x	13 Jun 1992	22 Dec 1994	22 Mar 1995
China (2) (3) ^x	11 Jun 1992	5 Jan 1993	21 Mar 1994
Colombia ^x	13 Jun 1992	22 Mar 1995	20 Jun 1995
Comoros	11 Jun 1992	31 Oct 1994	29 Jan 1995
Congo	12 Jun 1992	14 Oct 1996	12 Jan 1997
Cook Islands	12 Jun 1992	20 Apr 1993	21 Mar 1994
Costa Rica ^x	13 Jun 1992	26 Aug 1994	24 Nov 1994
Cote D'ivoire	10 Jun 1992	29 Nov 1994	27 Feb 1995
Croatia	11 Jun 1992	8 Apr 1996 A	7 Jul 1996
Cuba	13 Jun 1992	5 Jan 1994	5 Apr 1994
Cyprus	12 Jun 1992	15 Oct 1997	13 Jan 1998

Czech Republic	18 Jun 1993	7 Oct 1993 AA	21 Mar 1994
Democratic People's Republic Of Korea	11 Jun 1992	5 Dec 1994 AA	5 Mar 1995
Democratic Republic Of Congo	11 Jun 1992	9 Jan 1995	9 Apr 1995
Denmark	9 Jun 1992	21 Dec 1993	21 Mar 1994
Djibouti	12 Jun 1992	27 Aug 1995	25 Nov 1995
Dominica		21 Jun 1993 A	21 Mar 1994
Dominican Republic ^x	12 Jun 1992	7 Oct 1998	5 Jan 1999
Ecuador ^x	9 Jun 1992	23 Feb 1993	21 Mar 1994
Egypt ^x	9 Jun 1992	5 Dec 1994	5 Mar 1995
El Salvador ^x	13 Jun 1992	4 Dec 1995	3 Mar 1996
Equatorial Guinea		16 Aug 2000 A	14 Nov 2000
Eritrea		24 Apr 1995 A	23 Jul 1995
Estonia	12 Jun 1992	27 Jul 1994	25 Oct. 1994
Ethiopia	10 Jun 1992	5 Apr 1994	4 Jul 1994
European Union	13 Jun 1992	21 Dec 1993 AA	21 Mar 1994
Fiji	9 Jun 1992	25 Feb 1993	21 Mar 1994
Finland	4 Jun 1992	3 May 1994 A	1 Aug 1994
France	13 Jun 1992	25 Mar 1994	23 Jun 1994
Gabon	12 Jun 1992	21 Jan 1998	21 Apr 1998
Gambia	12 Jun 1992	10 Jun 1994	8 Sep 1994
Georgia		29 Jul 1994 A	27 Oct 1994
Germany	12 Jun 1992	9 Dec 1993	21 Mar 1994
Ghana	12 Jun 1992	6 Sep 1995	5 Dec 1995
Greece	12 Jun 1992	4 Aug 1994	2 Nov 1994
Grenada	3 Dec 1992	11 Aug 1994	9 Nov 1994
Guatemala ^x	13 Jun 1992	15 Dec 1995	14 Mar 1996
Guinea	12 Jun 1992	7 May 1993	21 Mar 1994

Guinea-Bissau	12 Jun 1992	27 Oct 1995	25 Jan 1996
Guyana	13 Jun 1992	29 Aug 1994	27 Nov 1994
Haiti	13 Jun 1992	25 Sep 1996	24 Dec 1996
Honduras ^x	13 Jun 1992	19 Oct 1995	17 Jan 1996
Hungary	13 Jun 1992	24 Feb 1994	25 May 1994
Iceland	4 Jun 1992	16 Jun 1993	21 Mar 1994
India ^x	10 Jun 1992	1 Nov 1993	21 Mar 1994
Indonesia ^x	5 Jun 1992	23 Aug 1994	21 Nov 1994
Iran (Islamic Republic Of) ^x	14 Jun 1992	18 Jul 1996	16 Oct 1996
Iraq		28 Jul 2009 A	26 Oct 2009
Ireland	13 Jun 1992	20 Apr 1994	19 Jul 1994
Israel ^x	4 Jun 1992	4 Jun 1996	2 Sep 1996
Italy	5 Jun 1992	15 Apr 1994	14 Jul 1994
Jamaica ^x	12 Jun 1992	6 Jan 1995	6 Apr 1995
Japan	13 Jun 1992	28 May 1993 A	21 Mar 1994
Jordan	11 Jun 1992	12 Nov 1993	21 Mar 1994
Kazakhstan	8 Jun 1992	17 May 1995	15 Aug 1995
Kenya ^x	12 Jun 1992	30 Aug 1994	28 Nov 1994
Kiribati	13 Jun 1992	7 Feb 1995	8 May 1995
Kuwait		28 Dec 1994 A	28 Mar 1995
Kyrgyzstan		25 May 2000 A	23 Aug 2000
Lao People's Democratic Republic		4 Jan 1995 A	4 Apr 1995
Latvia	11 Jun 1992	23 Mar 1995	21 Jun 1995
Lebanon	12 Jun 1992	15 Dec 1994	15 Mar 1995
Lesotho	11 Jun 1992	7 Feb 1995	8 May 1995
Liberia	12 Jun 1992	5 Nov 2002	4 Feb 2002
Libyan Arab Jamahiriya	29 Jun 1992	14 Jun 1999	12 Sep 1999

Liechtenstein	4 Jun 1992	22 Jun 1994	20 Sep 1994
Lithuania	11 Jun 1992	24 Mar 1995	22 Jun 1995
Luxembourg	9 Jun 1992	9 May 1994	7 Aug 1994
Madagascar	10 Jun 1992	2 Jun 1999	31 Aug 1999
Malawi	10 Jun 1992	21 Apr 1994	20 Jul 1994
Malaysia ^x	9 Jun 1993	13 Jul 1994	11 Oct 1994
Maldives	12 Jun 1992	9 Nov 1992	21 Mar 1994
Mali	30 Sep 1992	28 Dec 1994	28 Mar 1995
Malta	12 Jun 1992	17 Mar 1994	15 Jun 1994
Marshall Islands	12 Jun 1992	8 Oct 1992	21 Mar 1994
Mauritania	12 Jun 1992	20 Jan 1994	20 Apr 1994
Mauritius	10 Jun 1992	4 Sep 1992	21 Mar 1994
Mexico ^x	13 Jun 1992	11 Mar 1993	21 Mar 1994
Micronesia (Federated States Of)	12 Jun 1992	18 Nov 1993	21 Mar 1994
Monaco	11 Jun 1992	20 Nov 1992	21 Mar 1994
Mongolia ^x	12 Jun 1992	30 Sep 1993	21 Mar 1994
Montenegro (4)		23 Oct 2006 D	21 Jan 2007
Morocco ^x	13 Jun 1992	28 Dec 1995	27 Mar 1996
Mozambique	12 Jun 1992	25 Aug 1995	23 Nov 1995
Myanmar	11 Jun 1992	25 Nov 1994	23 Feb 1995
Namibia	12 Jun 1992	16 May 1995	14 Aug 1995
Nauru	8 Jun 1992	11 Nov 1993	21 Mar 1994
Nepal	12 Jun 1992	2 May 1994	31 Jul 1994
Netherlands (5)	4 Jun 1992	20 Dec 1993 A	21 Mar 1994
New Zealand	4 Jun 1992	16 Sep 1993	21 Mar 1994
Nicaragua ^x	13 Jun 1992	31 Oct 1995	29 Jan 1996
Niger	11 Jun 1992	25 Jul 1995	23 Oct 1995

Nigeria ^x	13 Jun 1992	29 Aug 1994	27 Nov 1994
Niue		28 Feb 1996 A	28 May 1996
Norway	4 Jun 1992	9 Jul 1993	21 Mar 1994
Oman	11 Jun 1992	8 Feb 1995	9 May 1995
Pakistan ^x	13 Jun 1992	1 Jun 1994	30 Aug 1994
Palau		10 Dec 1999 A	9 Mar 2000
Panama ^x	18 Mar 1993	23 May 1995	21 Aug 1995
Papua New Guinea	13 Jun 1992	16 Mar 1993	21 Mar 1994
Paraguay	12 Jun 1992	24 Feb 1994	25 May 1994
Peru ^x	12 Jun 1992	7 Jun 1993	21 Mar 1994
Philippines ^x	12 Jun 1992	2 Aug 1994	31 Oct 1994
Poland	5 Jun 1992	28 Jul 1994	26 Oct 1994
Portugal (3)	13 Jun 1992	21 Dec 1993	21 Mar 1994
Qatar		18 Apr 1996 A	17 Jul 1996
Republic Of Korea ^x	13 Jun 1992	14 Dec 1993	21 Mar 1994
Republic Of Moldova	12 Jun 1992	9 Jun 1995	7 Sep 1995
Romania	5 Jun 1992	8 Jun 1994	6 Sep 1994
Russian Federation	13 Jun 1992	28 Dec 1994	28 Mar 1995
Rwanda	10 Jun 1992	18 Aug 1998	16 Nov 1998
Saint Kitts And Nevis	12 Jun 1992	7 Jan 1993	21 Mar 1994
Saint Lucia	14 Jun 1993	14 Jun 1993	21 Mar 1994
Saint Vincent And The Grenadines		2 Dec 1996 A	2 Mar 1997
Samoa	12 Jun 1992	29 Nov 1994	27 Feb 1995
San Marino	10 Jun 1992	28 Oct 1994	26 Jan 1995
Sao Tome And Principe	12 Jun 1992	29 Sep 1999	28 Dec 1999
Saudi Arabia		28 Dec 1994 A	28 Mar 1995
Senegal	13 Jun 1992	17 Oct 1994	15 Jan 1995

Serbia		12 Mar 2001 A	10 Jun 2001
Seychelles	10 Jun 1992	22 Sep 1992	21 Mar 1994
Sierra Leone	11 Feb 1993	22 Jun 1995	20 Sep 1995
Singapore ^x	13 Jun 1992	29 May 1997	27 Aug 1997
Slovakia	19 May 1993	25 Aug 1994 AA	23 Nov 1994
Slovenia	13 Jun 1992	1 Dec 1995	29 Feb 1996
Solomon Islands	13 Jun 1992	28 Dec 1994	28 Mar 1995
Somalia		11 Sep 2009 A	10 Dec 2009
South Africa ^x	15 Jun 1993	29 Aug 1997	27 Nov 1997
Spain	13 Jun 1992	21 Dec 1993	21 Mar 1994
Sri Lanka ^x	10 Jun 1992	23 Nov 1993	21 Mar 1994
Sudan	9 Jun 1992	19 Nov 1993	21 Mar 1994
Suriname	13 Jun 1992	14 Oct 1997	12 Jan 1998
Swaziland	12 Jun 1992	7 Oct 1996	5 Jan 1997
Sweden	8 Jun 1992	23 Jun 1993	21 Mar 1994
Switzerland	12 Jun 1992	10 Dec 1993	21 Mar 1994
Syrian Arab Republic		4 Jan 1996 A	3 Apr 1996
Tajikistan		7 Jan 1998 A	7 Apr 1998
Thailand ^x	12 Jun 1992	28 Dec 1994	28 Mar 1995
The Former Yugoslav Republic Of Macedonia		28 Jan 1998 A	28 Apr 1998
Timor-Leste		10 Oct 2006 A	8 Jan 2007
Togo	12 June 1992	8 Mar 1995 A	6 Jun 1995
Tonga		20 Jul 1998 A	18 Oct 1998
Trinidad And Tobago	11 Jun 1992	24 Jun 1994	22 Sep 1994
Tunisia	13 Jun 1992	15 Jul 1993	21 Mar 1994
Turkey		24 Feb 2004 A	24 May 2004
Turkmenistan		5 Jun 1995 A	3 Sep 1995

Tuvalu	08 Jun 1992	26 Oct 1993	21 Mar 1994
Uganda	13 Jun 1992	8 Sep 1993	21 Mar 1994
Ukraine	11 Jun 1992	13 May 1997	11 Aug 1997
United Arab Emirates		29 Dec 1995 A	28 Mar 1996
United Kingdom Of Great Britain And Northern Ireland	12 Jun 1992	8 Dec 1993	21 Mar 1996
United Republic Of Tanzania ^x	12 Jun 1992	17 Apr 1996	16 Jul 1997
United States Of America	12 Jun 1992	15 Oct 1992	21 Mar 1994
Uruguay	4 Jun 1992	18 Aug 1994	16 Nov 1994
Uzbekistan ^x	---	20 Jun 1993 A	21 Mar 1994
Vanuatu	9 Jun 1992	25 Mar 1993	21 Mar 1994
Venezuela (Bolivarian Republic Of)	12 Jun 1992	28 Dec 1994	28 Mar 1995
Viet Nam ^x	11 Jun 1992	16 Nov 1994	14 Feb 1995
Yemen	12 Jun 1992	21 Feb 1996	21 May 1996
Zambia	11 Jun 1992	28 May 1993	21 Mar 1994
Zimbabwe	12 Jun 1992	3 Nov 1992	21 Mar

Countries marked ^x are CDM host parties with projects financed by different developed countries.

APPENDIX B

Table 12: Statistical Review of World Energy for Natural Gas Consumption British Petroleum (2012)

		Natural Gas Consumption (Million Tonnes of Oil equivalent)				
Continents	Countries	1990	2008	2009	2010	2011
North America	Canada	60.5	86.5	85.4	85.5	94.3
	United States of America	494.0	600.6	590.1	611.2	626.0
Europe	Austria	5.8	8.6	8.4	9.1	8.5
	Belgium	8.2	14.8	15.1	17.0	14.4
	Bulgaria	5.3	2.9	2.1	2.3	2.6
	Czech Republic	4.9	7.8	7.4	8.4	7.6
	Denmark	1.8	4.1	4.0	4.5	3.8
	Finland	2.3	3.6	3.2	3.6	3.2
	Germany	53.9	73.1	70.2	75.0	65.3
	Hungary	8.7	10.6	9.1	9.8	9.1
	Ireland	1.9	4.5	4.3	4.7	4.2
	Lithuania	5.0	2.9	2.5	2.8	3.1
	Netherlands	31.1	34.7	35.0	39.2	34.3
	Norway	1.9	3.9	3.7	3.7	3.6
	Poland	8.9	13.5	13.0	14.0	13.8
	Portugal	-	4.2	4.2	4.5	4.6
	Romania	27.7	14.3	11.9	12.2	12.5
	Russian Federation	366.8	374.4	350.7	372.7	382.1
	Slovakia	5.3	5.2	4.4	5.0	5.6
	Sweden	0.6	0.8	1.0	1.4	1.1
	Switzerland	1.6	2.8	2.7	3.0	2.6
	United Kingdom	47.2	84.5	78.0	84.6	72.2
Asia and Oceania	Australia	15.2	23.0	22.7	23.1	23.0
	China	13.7	73.2	80.6	96.8	117.6
	India	10.8	37.2	45.9	55.7	55.0
	Japan	43.3	84.4	78.7	85.1	95.0
	New Zealand	3.9	3.4	3.6	3.9	3.5
Africa	South Africa	0.2	3.4	3.0	3.5	104.3

Table 13: Statistical Review of World Energy for Total Petroleum Consumption British Petroleum (2012)

		Total Oil Consumption (Million Tonnes)				
Continents	Countries	1990	2008	2009	2010	2011
North America	Canada	79.8	102.5	97.1	102.7	103.1
	United States of America	772.5	875.8	833.2	849.9	833.6
Europe	Austria	10.8	13.3	12.8	12.9	12.5
	Belgium	23.8	36.8	32.2	33.5	33.7
	Bulgaria	6.8	4.6	4.2	3.8	3.5
	Czech Republic	8.4	9.9	9.7	9.1	9.1
	Denmark	9.0	9.5	8.5	8.4	8.3
	Finland	11.0	10.5	9.9	10.4	10.5
	Germany	127.3	118.9	113.9	115.4	111.5
	Hungary	9.3	7.5	7.1	6.7	6.5
	Ireland	4.4	9.0	8.0	7.6	6.8
	Lithuania	7.5	3.1	2.6	2.7	2.7
	Netherlands	35.7	51.1	49.4	49.9	50.1
	Norway	9.3	10.4	10.6	10.8	11.1
	Poland	15.8	25.3	25.3	26.7	26.3
	Portugal	11.1	13.6	12.8	12.5	11.6
	Romania	18.7	10.4	9.2	8.7	9.0
	Russian Federation	251.7	129.8	124.8	128.9	136.0
	Slovakia	5.0	3.9	3.7	3.9	3.7
	Sweden	17.4	15.7	14.6	15.3	14.5
	Switzerland	12.8	12.1	12.3	11.4	11.0
	United Kingdom	82.9	77.9	74.4	73.5	71.6
Asia and Oceania	Australia	31.6	42.5	42.2	43.4	45.9
	China	112.9	376.0	388.2	437.7	461.8
	India	57.9	144.1	153.7	156.2	162.3
	Japan	248.1	220.9	198.3	200.3	201.4
	New Zealand	4.9	7.2	6.9	7.0	6.9
Africa	South Africa	16.6	25.3	24.7	26.1	26.2

Table 14: Statistical Review of World Energy for Total Coal Consumption British Petroleum (2012)

		Total Coal Consumption (Million Tonnes of Oil equivalent)				
Continents	Countries	1990	2008	2009	2010	2011
North America	Canada	27.1	29.9	25.2	24.0	21.8
	United States of America	483.1	564.1	496.2	526.1	501.9
Europe	Austria	3.6	2.8	2.3	2.6	2.5
	Belgium	10.7	3.9	3.1	3.3	2.1
	Bulgaria	8.8	7.5	6.4	6.8	8.4
	Czech Republic	33.5	19.9	17.4	18.2	19.2
	Denmark	6.0	4.1	4.0	3.8	3.2
	Finland	3.3	3.0	3.3	4.3	3.3
	Germany	129.6	80.1	71.7	76.6	77.6
	Hungary	5.6	2.8	2.5	2.6	2.7
	Ireland	2.1	1.4	1.2	1.2	1.3
	Lithuania	0.6	0.2	0.1	0.2	0.2
	Netherlands	9.5	8.5	7.9	7.9	7.8
	Norway	0.8	0.7	0.5	0.6	0.6
	Poland	80.2	56.0	51.9	56.4	59.8
	Portugal	2.8	2.9	3.3	1.9	2.6
	Romania	11.7	7.4	6.6	6.1	7.1
	Russian Federation	180.6	100.4	91.9	90.2	90.9
	Slovakia	6.9	3.7	3.5	3.4	3.3
	Sweden	2.2	2.0	1.6	2.1	2.0
	Switzerland	0.3	0.1	0.1	0.1	0.1
	United Kingdom	64.9	35.6	29.9	31.0	30.8
Asia and Oceania	Australia	36.5	54.6	54.5	43.8	49.8
	China	507.1	1441.1	1579.5	1676.2	1839.4
	India	95.5	230.4	253.8	270.8	295.6
	Japan	76.0	128.7	108.8	123.7	117.7
	New Zealand	1.2	2.1	1.6	1.4	1.4
Africa	South Africa	66.4	95.1	89.9	91.3	92.9

Table 15: World Population from 1990 – 1997 World Bank (2012)

COUNTRY	YEAR							
	1990	1991	1992	1993	1994	1995	1996	1997
Australia	17,065,100	17,284,000	17,495,000	17,667,000	17,855,000	18,072,000	18,311,000	18,517,000
Austria	7,677,850	7,754,891	7,840,709	7,905,633	7,936,118	7,948,278	7,959,017	7,968,041
Belgium	9,967,379	10,004,486	10,045,158	10,084,475	10,115,603	10,136,811	10,156,637	10,181,245
Bulgaria	8,718,289	8,632,367	8,540,164	8,472,313	8,443,591	8,406,067	8,362,826	8,312,068
Canada	27,791,000	28,171,682	28,519,597	28,833,410	29,111,906	29,354,000	29,671,900	29,987,200
China	1,135,185,000	1,150,780,000	1,164,970,000	1,178,440,000	1,191,835,000	1,204,855,000	1,217,550,000	1,230,075,000
Czech Republic	10,333,355	10,308,578	10,319,123	10,329,855	10,333,587	10,327,253	10,315,241	10,304,131
Denmark	5,140,939	5,154,298	5,171,370	5,188,628	5,206,180	5,233,373	5,263,074	5,284,991
Finland	4,986,431	5,013,740	5,041,992	5,066,447	5,088,333	5,107,790	5,124,573	5,139,835
Germany	79,433,029	80,013,896	80,624,598	81,156,363	81,438,348	81,678,051	81,914,831	82,034,771
Hungary	10,373,988	10,373,400	10,369,341	10,357,523	10,343,355	10,328,965	10,311,238	10,290,486
India	873,785,449	891,910,180	910,064,576	928,226,051	946,373,316	964,486,155	982,553,253	1,000,558,144
Ireland	3,513,974	3,534,235	3,558,430	3,576,261	3,590,386	3,608,841	3,637,510	3,674,171
Japan	123,537,000	123,921,000	124,229,000	124,536,000	124,961,000	125,439,000	125,761,000	126,091,000

Lithuania	3,697,838	3,704,134	3,700,114	3,682,613	3,657,144	3,629,102	3,601,613	3,575,137
Netherlands	14,951,510	15,069,798	15,184,166	15,290,368	15,382,838	15,459,006	15,530,498	15,610,650
New Zealand	3,329,800	3,495,100	3,531,700	3,572,200	3,620,000	3,673,400	3,732,000	3,781,300
Norway	4,241,473	4,261,732	4,286,401	4,311,991	4,336,613	4,359,184	4,381,336	4,405,157
Poland	38,110,782	38,246,193	38,363,667	38,461,408	38,542,652	38,594,998	38,624,370	38,649,660
Portugal	9,983,218	9,967,878	9,969,953	9,982,591	10,004,081	10,030,376	10,057,861	10,091,120
Romania	23,201,835	23,001,155	22,794,284	22,763,280	22,730,211	22,684,270	22,619,004	22,553,978
Russian Federation	148,292,000	148,624,000	148,689,000	148,520,000	148,336,000	148,141,000	147,739,000	147,304,000
Slovakia	5,299,187	5,303,294	5,305,016	5,325,305	5,346,331	5,361,999	5,373,361	5,383,291
South Africa	35,200,000	35,933,108	36,690,739	37,473,796	38,283,223	39,120,000	40,000,247	40,926,063
Sweden	8,558,835	8,617,375	8,668,067	8,718,561	8,780,745	8,826,939	8,840,998	8,846,062
Switzerland	6,715,519	6,799,978	6,875,364	6,938,265	6,993,795	7,040,687	7,071,850	7,088,906
United Kingdom	57,247,586	57,424,897	57,580,402	57,718,614	57,865,745	58,019,030	58,166,950	58,316,954
United States of America	249,623,000	252,981,000	256,514,000	259,919,000	263,126,000	266,278,000	269,394,000	272,657,000

Table 16: World Population 1998-2005 World Bank (2012)

COUNTRY	YEAR							
	1998	1999	2000	2001	2002	2003	2004	2005
Australia	18,711,000	18,926,000	19,153,000	19,413,000	19,651,400	19,895,400	20,127,400	20,394,800
Austria	7,976,789	7,992,324	8,011,566	8,042,293	8,081,957	8,121,423	8,171,966	8,227,829
Belgium	10,203,008	10,226,419	10,251,250	10,286,570	10,332,785	10,376,133	10,421,137	10,478,617
Bulgaria	8,256,786	8,210,624	8,170,172	8,020,282	7,868,468	7,823,557	7,781,161	7,739,900
Canada	30,247,900	30,499,200	30,769,700	31,081,900	31,362,000	31,676,000	31,995,000	32,312,000
China	1,241,935,000	1,252,735,000	1,262,645,000	1,271,850,000	1,280,400,000	1,288,400,000	1,296,075,000	1,303,720,000
Czech Republic	10,294,373	10,283,860	10,272,322	10,236,491	10,204,853	10,207,362	10,216,016	10,235,828
Denmark	5,304,219	5,321,799	5,339,616	5,358,783	5,375,931	5,390,574	5,404,523	5,419,432
Finland	5,153,498	5,165,474	5,176,209	5,188,008	5,200,598	5,213,014	5,228,172	5,246,096
Germany	82,047,195	82,100,243	82,211,508	82,349,925	82,488,495	82,534,176	82,516,260	82,469,422
Hungary	10,266,570	10,237,530	10,210,971	10,187,576	10,158,608	10,129,552	10,107,146	10,087,065
India	1,018,471,141	1,036,258,683	1,053,898,107	1,071,374,264	1,088,694,080	1,105,885,689	1,122,991,192	1,140,042,863
Ireland	3,712,696	3,754,786	3,805,174	3,866,243	3,931,947	3,996,521	4,070,262	4,159,914
Japan	126,410,000	126,650,000	126,870,000	127,149,000	127,445,000	127,718,000	127,761,000	127,773,000
Lithuania	3,549,331	3,524,238	3,499,536	3,481,292	3,469,070	3,454,205	3,435,591	3,414,304
Netherlands	15,707,209	15,812,088	15,925,513	16,046,180	16,148,929	16,225,302	16,281,779	16,319,868
New Zealand	3,815,000	3,835,100	3,857,700	3,880,500	3,948,500	4,027,200	4,087,500	4,133,900

Norway	4,431,464	4,461,913	4,490,967	4,513,751	4,538,159	4,564,855	4,591,910	4,623,291
Poland	38,663,481	38,660,271	38,453,757	38,248,076	38,230,364	38,204,570	38,182,222	38,165,445
Portugal	10,129,290	10,171,949	10,225,836	10,292,999	10,368,403	10,441,075	10,501,970	10,549,424
Romania	22,507,344	22,472,040	22,442,971	22,131,970	21,803,129	21,742,013	21,684,890	21,634,371
Russian Federation	146,899,000	146,309,000	146,303,000	145,949,580	145,299,690	144,599,447	143,849,574	143,150,000
Slovakia	5,390,516	5,396,020	5,388,720	5,378,867	5,379,056	5,379,607	5,382,438	5,387,001
South Africa	41,899,683	42,923,485	44,000,000	44,909,738	45,533,292	46,116,494	46,664,771	47,198,469
Sweden	8,850,974	8,857,874	8,872,109	8,895,960	8,924,958	8,958,229	8,993,531	9,029,572
Switzerland	7,110,001	7,143,991	7,184,250	7,229,854	7,284,753	7,339,001	7,389,625	7,437,115
United Kingdom	58,487,141	58,682,466	58,892,514	59,107,960	59,325,809	59,566,259	59,867,866	60,224,307
United States of America	275,854,000	279,040,000	282,162,411	284,968,955	287,625,193	290,107,933	292,805,298	295,516,599

Table 17: World Population 2006-2011 World Bank (2012)

COUNTRY	YEAR					
	2006	2007	2008	2009	2010	2011
Australia	20,697,900	21,072,500	21,498,500	21,951,700	22,299,800	22,620,600
Austria	8,268,641	8,300,788	8,336,926	8,365,275	8,389,771	8,419,000
Belgium	10,547,958	10,625,700	10,709,973	10,796,493	10,895,785	11,008,000
Bulgaria	7,699,020	7,659,764	7,623,395	7,585,131	7,534,289	7,476,000
Canada	32,576,074	32,929,733	33,319,098	33,729,690	34,126,181	34,482,779
China	1,311,020,000	1,317,885,000	1,324,655,000	1,331,380,000	1,337,825,000	1,344,130,000
Czech Republic	10,269,134	10,334,160	10,424,336	10,487,178	10,519,792	10,546,000
Denmark	5,437,272	5,461,438	5,493,621	5,523,095	5,547,683	5,574,000
Finland	5,266,268	5,288,720	5,313,399	5,338,871	5,363,352	5,387,000
Germany	82,376,451	82,266,372	82,110,097	81,902,307	81,776,930	81,726,000
Hungary	10,071,370	10,055,780	10,038,188	10,022,650	10,000,023	9,971,000
India	1,157,038,539	1,173,971,629	1,190,863,679	1,207,740,408	1,224,614,327	1,241,491,960
Ireland	4,260,341	4,356,931	4,425,683	4,458,942	4,474,356	4,487,000
Japan	127,756,000	127,770,050	127,704,040	127,557,958	127,450,459	127,817,277
Lithuania	3,394,082	3,375,618	3,358,115	3,339,456	3,286,820	3,203,000
Netherlands	16,346,101	16,381,696	16,445,593	16,530,388	16,615,394	16,696,000
New Zealand	4,184,600	4,228,300	4,268,900	4,315,800	4,367,800	4,405,200

Norway	4,660,677	4,709,153	4,768,212	4,828,726	4,889,252	4,952,000
Poland	38,141,267	38,120,560	38,125,759	38,151,603	38,183,683	38,216,000
Portugal	10,584,344	10,608,335	10,622,413	10,632,482	10,637,346	10,637,000
Romania	21,587,666	21,546,873	21,513,622	21,480,401	21,438,001	21,390,000
Russian Federation	142,500,000	142,100,000	141,950,000	141,910,000	141,920,000	141,930,000
Slovakia	5,391,409	5,397,318	5,406,626	5,418,590	5,430,099	5,440,000
South Africa	47,730,946	48,257,282	48,793,022	49,320,150	49,991,300	50,586,757
Sweden	9,080,505	9,148,092	9,219,637	9,298,515	9,378,126	9,453,000
Switzerland	7,483,934	7,551,117	7,647,675	7,743,831	7,826,153	7,907,000
United Kingdom	60,595,632	60,986,649	61,393,521	61,811,027	62,231,336	62,641,000
United States of America	298,379,912	301,231,207	304,093,966	306,771,529	309,349,689	311,591,917

APPENDIX C

Table 18 : Electricity Generated (kWh) in the UNFCCC base year for the 28 considered countries

COUNTRIES	1985 Electricity generated (kWh)	1986 Electricity generated (kWh)	1987 Electricity generated (kWh)	1988 Electricity generated (kWh)	1989 Electricity generated (kWh)	1990 Electricity generated (kWh)
Australia						9.48308E+11
Austria						2.41784E+11
Belgium						5.21707E+11
Bulgaria				2.96854E+11		
Canada						1.99842E+12
China						6.70459E+12
Czech Republic						5.02095E+11
Denmark						1.96666E+11
Finland						2.00207E+11
Germany						3.56026E+12
Hungary	3.08383E+11	3.02952E+11	3.09354E+11			
India						1.82806E+12
Ireland						99681113628
Japan						4.44481E+12
Lithuania						1.60401E+11
Netherlands						9.14677E+11
New Zealand						1.20643E+11
Norway						1.49666E+11
Poland				1.37487E+12		
Portugal						2.31016E+11
Romania					8E+11	
Russian Federation						9.01033E+12
Slovakia						1.85776E+11
South Africa						8.91999E+11
Sweden						2.53062E+11
Switzerland						3.47077E+11
United Kingdom						2.40649E+12
United States of America						2.04978E+13

Table 19: Electricity generated (kWh) in the considered 28 countries

COUNTRIES	ELECTRICITY GENERATED (kWh)			
	2008	2009	2010	2011
Australia	1.36139E+12	1.35322E+12	1.26522E+12	1.35594E+12
Austria	2.98443E+11	2.84493E+11	2.97814E+11	2.83804E+11
Belgium	3.17728E+11	3.27542E+11	3.24641E+11	3.03715E+11
Bulgaria	1.67868E+11	1.41952E+11	1.43424E+11	1.59933E+11
Canada	2.62006E+12	2.49019E+12	2.55076E+12	2.63659E+12
China	2.01603E+13	2.17938E+13	2.35896E+13	2.57813E+13
Czech Republic	4.17737E+11	3.84917E+11	3.97857E+11	3.98024E+11
Denmark	2.10759E+11	1.96067E+11	1.98516E+11	1.82493E+11
Finland	2.06841E+11	1.97204E+11	2.18098E+11	2.04565E+11
Germany	3.17835E+12	2.996E+12	3.12046E+12	2.96851E+12
Hungary	2.47424E+11	2.21474E+11	2.25912E+11	2.16124E+11
India	4.59558E+12	5.05475E+12	5.37137E+12	5.69043E+12
Ireland	1.82073E+11	1.65159E+11	1.64643E+11	1.49608E+11
Japan	5.10507E+12	4.54848E+12	4.79902E+12	4.86781E+12
Lithuania	74939754220	63766411401	69101446410	72862233705
Netherlands	1.14366E+12	1.11884E+12	1.17449E+12	1.11866E+12
New Zealand	1.52541E+11	1.45744E+11	1.49422E+11	1.43461E+11
Norway	1.8524E+11	1.84326E+11	1.86793E+11	1.90429E+11
Poland	1.04406E+12	9.96648E+11	1.07208E+12	1.09887E+12
Portugal	4.01799E+11	4.05464E+11	4.13414E+11	4.16535E+11
Romania	3.73974E+11	3.22638E+11	3.14698E+11	3.32087E+11
Russian Federation	7.02803E+12	6.60277E+12	6.89414E+12	7.10147E+12
Slovakia	1.47653E+11	1.33772E+11	1.42308E+11	1.45723E+11
South Africa	1.31997E+12	1.25533E+12	1.29316E+12	1.31402E+12
Sweden	2.30447E+11	2.14667E+11	2.33313E+11	2.18573E+11
Switzerland	4.81187E+11	4.94653E+11	4.91648E+11	4.96959E+11
United Kingdom	2.33867E+12	2.1609E+12	2.237E+12	2.0666E+12
United States of America	2.38754E+13	2.2525E+13	2.328E+13	2.3005E+13

Table 20: Carbon Credit values

Countries	Carbon Credits
Australia*	-
Austria	102,651,878
Belgium	339,528,643
Bulgaria	320,234,248
Canada	746,175,495
Czech Republic	38,325,158
Denmark	25,243,900
Finland	172,744,926
Germany	-420,213,210
Hungary	222,883,447
Ireland	-41,878,628
Japan	-2,431,284,956
Lithuania	192,329,101
Netherlands	-792,067,875
New Zealand	183,764,236
Norway	245,745,077
Poland	-132,650,524
Portugal	-318,559,817
Romania	711,040,733
Russian Federation	7,632,434,226
Slovakia	201,728,545
Sweden	335,191,350
Switzerland	185,967,676
United Kingdom	1,269,770,544

* Assigned Amount Units issued by the United Nations was indicated in the source of data
UNFCCC (2008)