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MASTER'S THESIS

THE IMPACT OF ENERGY CONSUMPTION AND CARBON GAS EMISSIONS ON ECONOMIC GROWTH IN NEW EU MEMBER AND CANDIDATE COUNTRIES

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DECLARATION

I hereby declare that this Master's Thesis titled as "The Impact of Energy Consumption and Carbon Gas Emissions on Economic Growth in New EU member and candidate countries" has been written by myself without applying the help that can be contrary to academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

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YEMİN METNİ

Yüksek Lisans Tezi olarak sunduğum "Enerji Tüketimi ve Karbon Salınımının Ekonomik Büyüme Üzerindeki Etkisinin AB Üye ve Aday Ülkeler için incelenmesi." adlı çalışmanın, tarafımdan, bilimsel ahlak ve geleneklere aykırı düşecek bir yardıma başvurmaksızın yazıldığını ve yararlandığım eserlerin kaynakçada gösterilenlerden oluştuğunu, bunlara atıf yapılarak yararlanılmış olduğunu belirtir ve bunu onurumla doğrularım.

Tarih

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ÖZET

Yüksek Lisans Tezi
Enerji Tüketimi ve Karbon Salınımının Ekonomik Büyüme Üzerindeki Etkisinin AB Üye ve Aday Ülkeler için İncelenmesi
Yavuz Selman Duman

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Tezli Yüksek Lisans Programı

Enerji kavramı ve enerji kaynakları, çevrenin korunması, yenilenebilir enerji sistemleri ve nükleer enerji gibi ilgili konular özellikle son yıllarda oldukça önem kazanmıştır. Bu durumun temelinde yatan nedenlerden en önemlisi enerjinin hem üretim sürecinde hem de günlük yaşamda hayati bir unsur haline gelmesi ve böylelikle ekonomik gelişmeyi etkilemesidir. Diğer taraftan bu konuya asıl önem kazandıran nokta, yüzyıllardır yoğun olarak kullanılan enerji kaynaklarının belirli bölgelerde yeralmasının bu bölgelerde tekel oluşturması ve enerji kaynaklarının gelecekte azalacağına dair beklentilerin oluşmasıdır.

Bununla beraber, söz konusu kaynakların kullanımının da hayati öneme sahip olmasının nedenleri (1) bu kaynakların çevresel bozunmaya yol açan yüksek miktarda karbon dioksit salınımı gerçekleştirmesi; (2) kaynakların sınırlı olması ve bu kaynaklara belirli ülkelerin sahip olması ve bu nedenle diğer birçok ülkenin Gayri Safi Yurt İçi Hasıla (GSYIH) üzerinde yük oluşturacak biçimde ithalatçı konumda bulunmasıdır.

Yukarıda belirtilen nedenlerden ötürü enerji tüketimi, karbondioksit salınımı ve ekonomik büyüme arasındaki ilişki yakın dönemde iktisatçılar arasında ilgi çeken bir konu haline gelmiştir. Uygun politikaları belirlemek amacıyla çeşitli modeller, değişkenler ve farklı örneklemler kullanarak yapılan çalışmalar bu nedensel ilişkinin yönünü araştırmayı amaçlamıştır.

Bu çalışmanın amacı Arellano-Bond Genelleştirilmiş Momentler Metodu (GMM) modeli ve Granger nedenselliği kullanılarak enerji tüketimi, ekonomik

büyüme ve karbon dioksit salınımı arasındaki ilişkiyi araştırmaktır. Çalışmanın örneklemi Avrupa Birliği (AB) üyelerinden Merkez Doğu Avrupa (CEE) ülkeleri; Estonya, Letonya, Litvanya, Polonya, Çek Cumhuriyeti, Slovak Cumhuriyeti, Slovenya, Macaristan, Bulgaristan, Romania ve AB'ne aday üç ülke; Türkiye, Makedonya ve Hırvatistan'dan oluşmaktadır. Çalışmanın veri seti 1997-2008 yıllarını kapsamaktadır.

Anahtar Kelimeler: Ekonomik Büyüme, Enerji Tüketimi, Karbon Dioksit Salınımı, Arellano-Bond Genelleştirilmiş Momentler Metodu (GMM)

ABSTRACT

Master's Thesis
The Impact of Energy Consumption and Carbon Gas Emissions on Economic Growth in New EU Member and Candidate Countries
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Master's Program

Especially in the recent years, the concept of energy and the related issues such as energy reserves, environmental protection, renewable energy systems and nuclear energy have become very significant. One of the most important reasons underlying this reality is the fact that energy has become a vital input in both the production process and the daily life itself which consequently affects economic growth. Moreover, the fact that the reserves of the abundant energy sources that have been used for centuries are accumulated in specific regions which establish a kind of monopoly and these reserves are expected to diminish in the future holds critical importance.

Furthermore, the uses of these sources are also vital due to the fact that, (1) they are emitting high amounts of carbon dioxide which leads to environmental degradation; (2) because the reserves are limited and obtained by specific countries, most of the other countries are importers which create a burden on their Gross Domestic Product (GDP).

For the reasons asserted above, the relationship between energy consumption, carbon dioxide emissions and economic growth has been a topic of interest among economists especially in the recent years. In order to determine the adequate policy applications, the studies have investigated the direction of causal relationship using a variety of models, variables and different samples.

The aim of this study is to reexamine the nexus between energy consumption, economic growth and carbon dioxide emissions using Arellano-Bond's system Generalized Method of Moments (GMM) model and Granger Causality. The sample of the study consists of the European Union (EU) member states of Central Eastern Europe (CEE) namely; Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovak Republic, Slovenia, Hungary, Bulgaria, Romania and the three candidate countries; Turkey, Macedonia FYR and Croatia for the data between the years 1997- 2008.

Key Words: Economic Growth, Energy Consumption, CO_2 Emissions, Arellano-Bond system GMM

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METHODOLOGY, DATA AND ANALYSIS

ABBREVIATIONS

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
C_6H_{14}	Hexane
C_7H_{16}	Heptane
C_8H_{18}	Octane
CEE	Central Eastern Europe
CH_4	Methane
CIS	Commonwealth of Independent States
CO_2	Carbon Dioxide
DC	Developed Countries
EC	Energy Consumption
EIA	U.S. Energy Information Administration
EKC	Environmental Kuznets Curve
ETS	Emissions Trading Scheme
EU	European Union
FSU	Former Soviet Union
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GMM	Generalized Method of Moments

GNP	Gross National Product
HLW	High-Level Radioactive Waste
IEA	International Energy Agency
IEM	Internal Energy Market
ILW	Intermediate-Level Radioactive Waste
J	Joule
JET	Joint European Torus
kJ	Kilojoule
LDC	Less Developed Countries
LLW	Low-Level Radioactive Waste
LNG	Liquid Natural Gas
LPG	Liquefied Petroleum Gas
mJ	Megajoule
MSW	Municipal Solid Waste
NO, NO_2, and N_2O	Nitrogen Oxides
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
p.	Page Number
PP	Phillips-Perron
PV	Solar Photovoltaic Systems
SO_2 and SO_3	Sulfur Oxides
TPES	Total Primary Energy Supply
WDI	World Development Indicators

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INTRODUCTION

Energy is a significant leverage and igniter for economic and human development. Along with the boost in global demand for energy since 1990, misuse of energy has led to an increase in the greenhouse gas emissions thus causing the degradation of biodiversity and the quality of water and air. Moreover due to the fact that energy reserves are not equally divided among countries by nature, there have been conflicts among the suppliers and consumers.

With the emergence of globalization, energy has become a topic of either conflict or cooperation among the countries. Starting with the geographical discoveries and evolving with the industrialization, the need for energy has become vital, such that it created serious crisis during the years 1973 and 1979. It was the result of a war between Israel and the Arabs, followed by a sudden cut of the oil export from the Arab nations to the allies of Israel. In this era of oil crisis there has also been an economic dislocation in which, the economic wealth shifted from the oil consuming countries to the oil exporting nations. Due to the scarcity of oil imports the world suffered from the rising energy costs. The period revealed an inconvenient truth that the industrial world in which we live does not bear the capacity to handle the slightest deviation from the accustomed high usage of energy. As a result the questions arise in minds such as; "Could it be possible to pursue the adequate level of production with less energy?", "Which is less costly to the society, less use of energy or creating alternative means of energy?" "If energy scarcity is the case are we ready to change our way of living?" In this regard, energy has become one of the major subjects of 20th century that its supply and demand amounts have become to be observed as an indicator of the development of a country.

Energy is one of the most vital inputs of production and with improvement of technology and machinery the production process is being more and more dependent on the means of energy. The need for energy might as well contribute to the rise of technological advances and development of industry. Such that, the increasing demand for energy created incentives to improve current technology in order to produce more reliable energy which in return helped enhance the level of the society. History presents us with such examples; when wood was the abundant energy resource, apart from being the main element of construction, countries slowly became deforested. Consequently coal became the main energy resource however, it created air pollution thus the need for energy and the drawbacks urged people to search for alternative energy resource and the means to extract and use them.

Today, the world cannot be compared with the past due to the fact that the level of consumption, population and technology, overall the need for abundant energy resources is far more enhanced than ever. Therefore there is no clear cut answer to any of the questions asked regarding the conditions the society is in and will be in the years ahead. The only tangible fact is that, with today's scarce resources; issues such as renewable energy, energy security, energy diversification and environmental protection in consuming and producing energy; in general energy planning have gained significance. Thereto the decisions and the choices of today will affect generations to come and the world they will exist in.

The overall objective of my thesis is to apply the dynamic panel Granger-causality tests in order to test the effects of energy consumption and carbon gas emissions on economic growth. The data will consist of the carbon dioxide (CO_2) emissions, energy consumption and gross domestic product (GDP) between the years 1997-2008 of the European Union (EU) member states of Central Eastern Europe (CEE) namely; Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovak Republic, Slovenia, Hungary, Bulgaria, Romania and the three candidate countries; Turkey, Macedonia FYR and Croatia.

Part one of this study will constitute of the definitions, diversifications and the current reserves of the energy resources. Furthermore present the most recent forecasts for the abundant energy sources. Part two will state the energy profiles of the corresponding countries of EU member states of CEE and the three candidate countries. The CEE countries' characteristic is that they are transition economies such that, with the disintegration of the Soviet Bloc, these economies have been in the process of transforming into market economies. The study will indicate the differences between the

CEE countries' energy resource components that ignite the economic growth before and after the transition along with the change in the CO_2 emissions.

Part three will dwell on the energy economics literature regarding the relationship between energy consumption, carbon gas emissions and long term economic growth. Part four will consist of the methodology, data, and the results of the analysis and interpretation of the results. In order to fulfill these objectives this study will use the Dynamic Panel Data Model. The study will be concluded with a conclusion comprising the overall analysis and the research.

PART ONE

ENERGY RESOURCES AND TECHNOLOGIES

1. Primary Energy Resources

The concept of energy has been defined in the dictionary of energy as; "Energy is the ability to do work where work is the action of a force acting on an object undergoing a displacement. Matter in motion is said to have kinetic energy because of its ability to change the motion of another object. Matter in a favorable position, such as water atop a dam, is said to have potential energy because of its ability to change the motion of another object once the water flows over the dam" (Cleveland and Morris, 2006: 143). Furthermore Quaschning (2005) makes a similar definition stating that "energy is the ability of a system to cause exterior impacts, for instance a force across a distance. Input or output of work changes the energy content of a body." Moreover energy is separated into nine categories according to their form of existence and transformation which are; mechanical energy, potential energy, kinetic energy, thermal energy, magnetic energy, electrical energy, radiation energy, nuclear energy, chemical energy.

There has been a common misperception about energy such as "energy losses" or "energy gains" nevertheless the reality is clarified by the law of energy conservation which states that "energy can neither be created nor destroyed" (Babits, 1963: 208) but it can be transformed from one form to another under an isolated environment. The most observable example is that; natural oil is preserved as potential energy, after being processed to fuel it becomes chemical energy and the heat produced when burnt in a combustible engine it transforms into thermal energy finally the movement of a car is kinetic energy. In this regard natural resources contain energy hence we use it to accelerate a vehicle or create work. "The particularity of energy is to exist in different forms: mechanical, heat, nuclear, etc., and it is very often necessary to convert one form of energy into another" (Ngo, 2008: 2).

Internationally accepted unit of energy is joule (J) nevertheless this unit is too small for measurement thus kilojoule (kJ) or megajoule (mJ) is used for simplicity (1000

J= 1 kJ and 1 kJ = 10^6 mJ). For further reference Table 1-1 demonstrates today's most commonly used energy units and their conversion to each other.

Table 1-1 Conversion Factors for Energy

	kJ	Kcal	kWh	kg ce	kg oe	m^3 gas	BTU
1 kilojoule (kj)	1	0,2388	0,000278	0,000034	0,000024	0,000032	0,94781
1 kilocalorie (kcal)	4,1868	1	0,001163	0,000143	0,0001	0,00013	3,96831
1 kilowatt-hour (kWh)	3.600	860	1	0,123	0,086	0,113	3.412
1 kg coal equivalent (kg ce)	29,308	7.000	8,14	1	0,7	0,923	27,779
1 kg oil equivalent (kg oe)	41,868	10.000	11,63	1,428	1	1,319	39,683
1 m^3 natural gas	31,736	7.580	8,816	1,083	0,758	1	30,080
1 British Thermal Unit (BTU)	1,0551	0,252	0,000293	0,000036	0,000025	0,000033	1

Source: Quaschning, 2005, p.2

In order to pursue our life standards and carry on, or sustain our lives, we need an adequate amount of energy. The everyday meal we eat and consume corresponds to a major part of our energy need. Nevertheless fuel energy is also needed to cook and preserve these meals. In the agricultural society energy was needed for cropping, growing and storing food, making clothes and building houses. In the industrial society much more energy is needed for the same purposes and many other activities that have been evolved with the increase in population and use of technology such as communication, transportation, construction and lighting.

Earl Cook (1971) in his study "The Flow of Energy in an Industrial Society" has demonstrated the historical energy consumption stages of man in Table 1-2 via six periods. According to Cook (1971) man needs 2,000 kcal per day to sustain his life thus the primitive man supplied his energy demand from food. Furthermore Cook (1971) demonstrates that with the domestication of fire have increased the energy demand up to around 4,000 kcal and consequently the demand for energy rises through time along with the evolution of man's demands and needs.

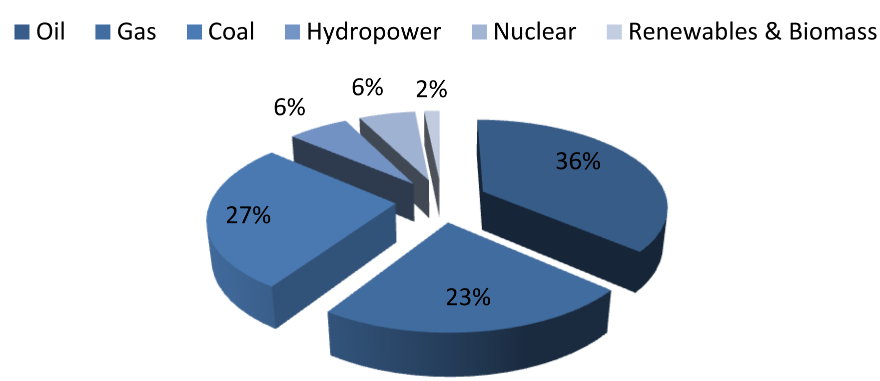
Table 1-2 Historical Energy Consumption

Period	Daily Per Capita Consumption 1.000 kcal				
	Food	Home and Commerce	Industry and Agriculture	Transportation	Total
Technological Man	10	66	91	63	230
Industrial Man	7	32	24	14	77
Advanced Agricultural Man	6	12	7	1	26
Primitive Agricultural Man	4	4	4	0	12
Hunting Man	3	2	0	0	5
Primitive Man	2	0	0	0	2

Source: Cook, 1971, p.136

As well as their use, the primary energy resources themselves have evolved through time due to their demand, supply, technology and the density of the raw material that enables to transform into energy. In the early times man used firewood as the source of energy, today we use oil, gas, coal, uranium as the essence of nuclear energy, wind power, tidal power, solar power, geothermal, biomass and hydro power. Some are more abundantly used, in other terms more economical and rich in reserves than others nevertheless in the future we might as well be using some other type of non-conventional energy or perhaps we could revert back to wood.

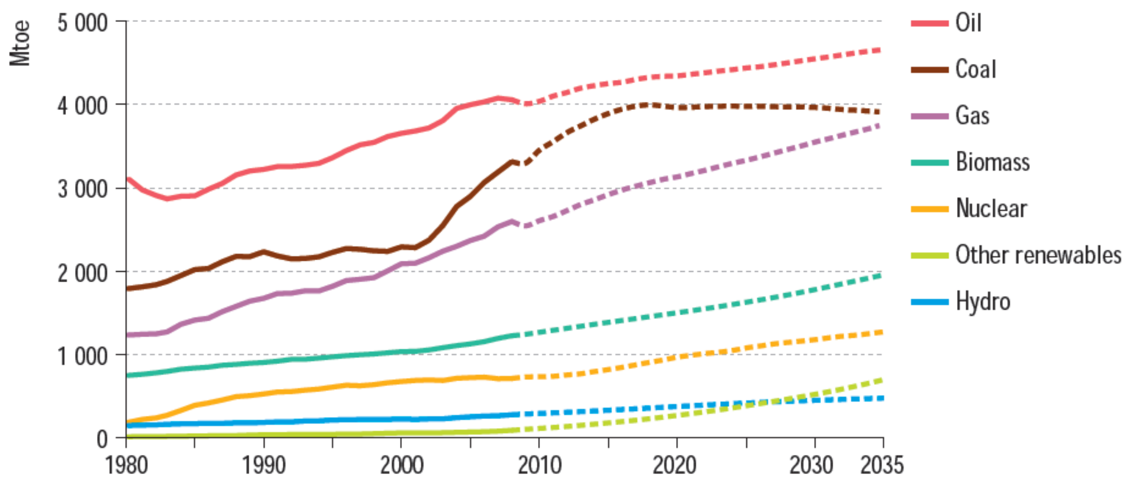
Figure 1-1 World Consumption of Primary Energy by Source in 2006



Source: EIA, 2006

World energy consumption profile with the most recent data show that oil with 36% of overall primary energy consumption is the first, followed by 27% coal and 23% gas is demonstrated in Figure 1-1. Furthermore, the projections up to 2035 about energy demand by fuel indicate that oil remains as the dominant fuel while natural gas is expected to surpass coal by the end of 2035 and become the second major fuel source. Figure 2-2 depicts the trends in world primary energy demand by fuel between 1980 and 2035.

Figure 1-2 World Primary Energy Demand by Fuel



Source: EIA, 2010, p.184

Primary natural energy resources are most commonly defined in two categories: depletable and renewable. As it is clear from the definition, depletable resources are those that run out faster than it is generated in nature. On the other hand, renewable resources are those that are either replenish or can be generated by nature if there is no refraction throughout the natural cycle.

1.1. Depletable Resources

Depletable resources are categorized into two categories based on the fuel types they are used to generate. These categories are commonly known as fossil fuels and nuclear power. It’s the limited availability of the depletable resources that creates the scarcity in the world thus leads conflicts between nations those who possess more reserves than others.

1.1.1. Fossil Fuels

In today's economic world fossil fuels; coal, oil and natural gas are the major providers of overall consumed energy. The dictionary for energy defines fossil fuel as "a fuel such as coal, oil and natural gas, produced by the decomposition of ancient (fossilized) plants and animals" (Cleveland and Morris, 2006: 171). According to this definition "fossil fuels come from layers of prehistoric carbonaceous materials that have been compressed over millions of years to form energy-dense concentrations of solid, liquid, or gas, which can be extracted and combusted to meet human energy requirements" (Vanek and Albright, 2008: 107).

In other words, fossil fuels are the remains of some plants and animals that have been preserved in soil and various levels of the earth's crust over millions of years and eventually transformed and metamorphosed into what we today use such as coal. On the other hand oil and natural gas are assumed to pass through a similar natural transformation process with one slight difference that is, oil and natural gas are originated "primarily from plankton that fell to the ocean floor near continental shorelines where it was covered by layers of sediment and eventually transformed into gaseous and liquid hydrocarbon through high pressure and temperature over millions of years" (Jaccard, 2005: 8).

1.1.1.1. Coal

"Geologically, coal is a complex substance derived from buried plant material which underwent alteration due to heat, pressure and chemical and biochemical processes" (Chatterjee, 2006: 5). The process of alteration causes coal to have different types and intensities such as, peat, lignite, bituminous coal and anthracite. In the economic and common concept when we consider coal in the household it is bituminous coal that is referred to. The analysis of coal indicates that it is principally comprises of carbon, hydrogen, oxygen and earthy matter, and also small quantities of nitrogen, moisture, sulphur and phosphorus. Overall, it is clear that coal contains organic material and carbon in varying proportions according to the transformation period of time it encounters, ergo the older the coal, the richer it gets in terms of carbon. Table 1-3 presents a detailed chemical analysis of different types of coal. Amongst the types of coal, anthracite is the oldest and richest in terms of carbon intensity with 90% as well as heat value.

Table 1-3 A Comparison of Different Types of Coal

Type of Coal	Color	Water Content (%)	Relative Sulfur Content	Carbon Content (%)	Average Heat Value (BTU/pound)	2007 Cost at Mine for 2000 lb of Coal ($)
Lignite	Dark Brown	45	Medium	30	6.000	14,82
Subbituminous Coal	Dull Black	20 to 30	Low	40	9.000	10,69
Bituminous Coal	Black	5 to 15	High	50 to 70	13.000	40,80
Anthracite	Black	4	Low	90	14.000	52,24

Source: Raven, Berg and Hassenzahl, 2010, p.236

Coal is considered as a source for producing heat through a burning process. Hence the principle of burning coal is to transform the heat energy into mechanical energy. “In modern thermal power generation plants, coal is used to heat water in boilers, transform the water into superheated steam and then direct the steam at great force for moving turbines” (Chatterjee, 2006: 22). It is the steam generated from water that is boiled by burning coal which forces the turbines to accelerate and transform energy. The aforementioned intensity of carbon in coal comes into consideration at this point such that, if the volatile matter of coal is too high, the coal will burn faster than adequate steam to move the turbines is produced thus there will be loss of heat or some carbon will remain unburnt. Therewithal, if the volatile matter is too low it will result a slowdown in the process of boiling the water thus it will take more time to generate steam.

Due to the fact that coal inhere high amounts of carbon, sulfur and nitrogen there are extensive drawbacks for burning coal such as air pollution (including CO_2 emissions) and decomposition in water quality. “CO_2 emitted by burning of coal is a major source of air pollution, and is the single most responsible agent for global warming or (as it is called now-a-days) the 'green house effect'" (Chatterjee, 2006: 41). Apart from the effect of carbon burnt in coal, the remaining volatile matter of coal has varying drawbacks. "Much bituminous coal contains sulfur and nitrogen that, when burned, are released into the atmosphere as sulfur oxides (SO_2 and SO_3) and nitrogen oxides (NO, NO_2, and N_2O). Sulfur oxides and the nitrogen oxides NO and NO_2 form acids when they react with water" (Raven et.al., 2010: 239). Eventually, the increased acid ratio (normal rain's acidic level is pH 5,6) in lakes and streams cause deforestation and decrease in aquatic life.

World proven coal reserves are around 860 to 900 billion tones of which 47% constitutes bituminous coal, 30% is sub-bituminous coal and the remaining 27% is lignite. Amongst the overall countries which obtain coal reserves the highest reserves are in USA, Russian Federation and China with around 60% of the world reserves (WEC, 2010). World Resources Institute indicates that today's proven coal reserves would compensate the demand for over 200 years with the recent consumption rate. Moreover, it is also stated that the unattained coal reserves which are currently too expensive to mine are expected to last for nearly 1000 years, however with the current price of coal mining such resources would cost more than its benefits. (Raven et.al., 2010). Although there are countries that attain the major share in terms of coal reserves, there have not been significant conflicts due to the coal wealth of the nations. Nearly none of the countries have an apparent scarcity in terms of coal reserves.

1.1.1.2. Petroleum

Petroleum or more commonly referred to as oil is "formed from plankton deposited on the ocean bed; organic matter mixed with sediment accumulated in layers at great depth" (Ngo, 2008: 18). Moreover oil is an easily flammable fossil fuel source which is composed of hundreds of hydrocarbon compounds of which 50-90% is carbon, 11-14% of hydrogen, minor quantities of oxygen, nitrogen, sulphur and metal. There are two states of petroleum that is in use today which are oil and natural gas. Under surface conditions oil is a petroleum fluid in the liquid state just as natural gas is a petroleum fluid in a gaseous state (Fanchi, 2005).

1.1.1.2.1. Oil

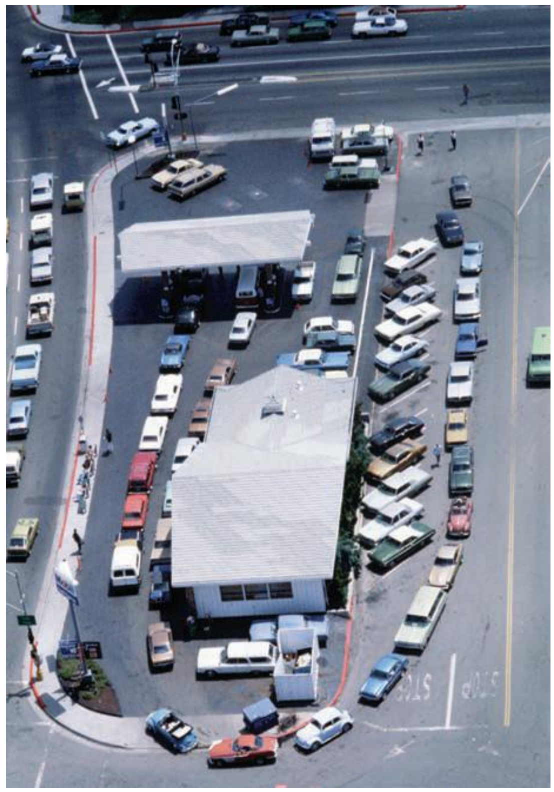
Although coal was the most significant energy source, oil became increasingly important after the industrial revolution. The transition from one source to another was mainly for the reason that oil was more accessible, easier to transport and in environmental terms greenhouse gas emissions is lesser than that of coal. As well as coal; the density of oil depends on the process it encounters during the historical transformation process, temperature and pressure.

Today natural oil is not used in its crude or natural form but rather it undergoes a transformation process and in this process it alters into various types based on the level of boiling points. From the highest boiling level to the lowest, the types are; asphalt, lubricants, diesel oil, heating oil, kerosene, aviation fuel, gasoline and finally the byproduct of heating oil is the gases we use in everyday life such as heating the oven. (Raven et.al., 2010)

Oil has been in use for over 3000 years in different forms such as candles, torches and lamps however, the first oil well was established in 1859. The capacity of the first well was around ten to twenty five barrels a day with a market price of $20 to $40 per barrel (Nersesian, 2007: 106). With the exploration of a new source of energy it was a matter of time that new investors get their hands on the, as it was referred to than "black gold" (Ngo, 2008: 19). Since then oil has been one of the most convenient energy resources to be used due to fact that the liquid state enabled it to easily transport from the source to the end user. Nevertheless unlike coal the oil reserves are not commensurate among the nations hence there have been and still are significant crisis caused by the scarcity of oil sources. Those whom possess control over the oil reserves became more distinguished after the World War I and had been separated into seven multinational companies most commonly known as the "seven sisters", whom constituted of: Exxon, Shell, British Petrol (BP), Gulf, Texaco, Mobil and Chevron. These firms had been competing in terms of market share however, cooperating in improving and exploring the reserves.

During the late 1950s oil producers, apart from the seven sisters, especially Russia, pursued a cheaper oil policy which has forced the seven sisters to follow, thus the price of oil dropped leading to a decrease in the profit margins.

Figure 1-3 Long Lines at a filling station in 1973



Source: Raven et.al., 2010: 246

The oil producing countries of the Middle East were not content with these price cuts hence the first Arab Petroleum Congress was held, consequently giving birth in 1960 to the Organization of Petroleum Exporting Countries (OPEC) with the founders: Saudi Arabia, Iran, Iraq, Kuwait and Venezuela. OPEC acted as a regulatory authority in order to prevent any more cuts and preserve the oil market stability and the price level at a profitable margin. Today "the mission of the Organization of the Petroleum Exporting Countries (OPEC) is to coordinate and unify the petroleum policies of its Member

Countries and ensure the stabilization of oil markets in order to secure an efficient, economic and regular supply of petroleum to consumers, a steady income to producers and a fair return on capital for those investing in the petroleum industry." (OPEC, 2011a)

Table 1-4 World oil reserves 2010

Country	Oil Reserves	Percent of World Total
Saudi Arabia	259,9	19,2
Canada	175,2	12,94
Iran	137,6	10,16
Iraq	115	8,5
Kuwait	101,5	7,5
Venezuela	99,4	7,34
United Arab Emirates	97,8	7,22
Russia	60	4,43
Libya	44,3	3,27
Nigeria	37,2	2,75
Kazakhstan	30	2,22
Qatar	25,4	1,88
China	20,4	1,51
United States	19,2	1,42
Brazil	12,8	0,95
Algeria	12,2	0,9
Mexico	10,4	0,77
Azerbaijan	9,5	0,7
Angola	7	0,52
Norway	6,7	0,49
Rest of World	72,2	5,33

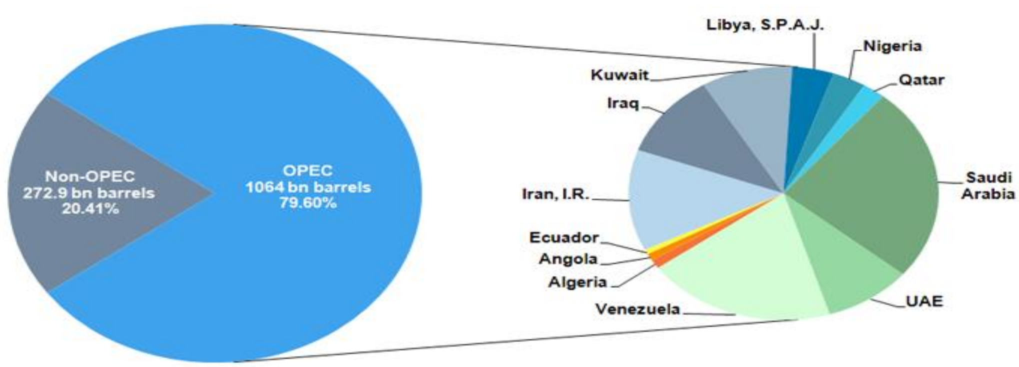
Source: EIA, 2010, p.37

During 1960 OPEC nations were supplying 38 percent of the world oil demand, 47 percent in 1965, 56 percent when the first crises break out in 1973 (Nersesian, 2007) and around 79 percent in 2009. The oil crisis of 1973 is one of the most memorable "oil shocks" which clearly presents, not only the fact that oil reserves are abundant in one region but also, depending on one type of energy source could create serious ramifications when faced with an impasse between the exporters and importers of oil.

Although there have been other reserves around the world (Table 1-4), as aforementioned the Middle East oil was supplying 79% (Figure 1-5) of the world oil consumption hence any divergence from the supply of price had severe affects on the economies. In Figure 1-3 the long lines at a filling station is presented as an example to the results of the oil supply cutback in 1973.

The future projections indicate that global oil production has already reached its peak and 80 percent of the current production is originated from the reserves that are explored before 1973. Even though the oil consumption is increasing there are few new reserves to compensate that demand. “Analysts say the world must move quickly to develop alternative energy sources because the global demand for energy will only continue to increase even as production declines” (Raven et.al., 2010: 246). In the light of the foregoing it would be logical to state that if countries do not diversify their energy resources with renewable or alternative means of energy resources but rather keep relying on oil, long lines at filling stations are most likely to repeat just as it did back in 1973.

Figure 1-4 OPEC Share of World Crude Oil Reserves



OPEC proven crude oil reserves , end 2009
(billion barrels)

Saudi Arabia	264.59	24.9%	Iraq	115.00	10.8%	Libya, S.P.A.J	46.42	4.4%	Algeria	12.20	1.1%
Venezuela	211.17	19.8%	Kuwait	101.50	9.5%	Nigeria	37.20	3.5%	Angola	9.50	0.9%
Iran, I.R.	137.01	12.9%	UAE	97.80	9.2%	Qatar	25.38	2.4%	Ecuador	6.51	0.6%

Source: OPEC, 2011b

Oil drilling, exploration, storing and transporting requires extensive amount of engineering. The first environmental effects of the discovery of oil and drilling came in to effect when the drilling areas were wiped off of trees and natural life due to heavy construction gears and equipments used to search or drill oil. Even though today the drilling and pumping technology is highly developed from time to time news cover stories about oil leaks hence the first drilling machinery were far less developed which caused oil to leak to the soil that caused to the loss of plants and vegetation. Furthermore, storing the extracted oil and transporting had serious drawbacks such that “oil was stored in pits dug into the ground, soon replaced by wooden, and later, by metal tanks” (Nersesian, 2007: 106). Today transporting of around 1,5 billion tones of crude oil is transported via sea which constitutes 40 percent of the overall maritime freight (Ngo, 2008).

Figure 1-5 Aftermath of an oil spill

Source: Raven et.al., 2010, p.248

Oil tanker accidents, leaks and shipwrecks have caused serious number of natural disasters. Although the numbers of disasters have been reduced with the development of technologies used however, the effects do not change when they do happen. Besides, in the early times is a transport ship carries on board for example 30.000 tones of oil, today oil companies have gigantic tankers which carry more than 200.000 tones of oil, viz much more amount of oil pollutes oceans in the occurrence of an accident. “In 1989 the supertanker Exxon Valdez hit Bligh Reef and spilled 260,000 barrels (10.9 million gallons = 41.2 million liters) of crude oil (Figure 1-4) into Prince William Sound along the coast of Alaska” (Raven et.al., 2010: 248).

Apart from the effects caused during the drilling, storing and transporting there is also the most commonly known CO_2 emissions caused on account of the burning of oil and refining. “Every gallon (1 gallon = 3,785 liters) of gasoline you burn in your automobile releases an estimated 9 kg (20 lb) of CO_2 into the atmosphere. As CO_2 accumulates in the atmosphere, it insulates the planet, preventing heat from radiating back into space” (Raven et.al., 2010: 247). As the proportion of CO_2 in the atmosphere gas diversification increase, it prevents the solar heat to radiate back into space consequently rising the temperature of the earth’s surface. The global climate warming more rapidly than it does in its natural process causes the glaciers melt which from one facet it increases the level of the oceans and on the other, large amounts of pure water decreases the salt quantity in the oceans. Both of which can lead to significant natural disasters such that the first could cause coastal cities to submerge under water, while the second could damage the marine life.

1.1.1.2.2. Natural Gas

Natural gas is partly different from oil in terms of different hydrocarbons it obtains: methane, ethane, butane and propane. “The principal constituent is methane (CH_4) which constitutes on an average 85% of natural gas. This is followed by ethane or C_2H_6 (10%), propane or C_3H_8 (3%). The balance 2% may comprise butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), heptane (C_7H_{16}) and octane (C_8H_{18})” (Chatterjee, 2006: 76). Gas originates around the same time as oil does however; due to its gaseous state it tends to migrate under soil thus there could be natural gas reserves where no oil exists.

Unlike oil natural gas has been encountered by the primitive people nevertheless it has been confused with mysterious beings such that, “natural gas in many spots have been burning since time immemorial, and these “eternal” fires were worshipped by people" (Chatterjee, 2006: 75). Beyond that, even in the early ages of the oil industry much of the natural gas generated out of the processed oil was burnt or released into the atmosphere. Until after the technology to store and transport the natural gas was invented and a market for natural gas was established, than it was possible to use natural gas. "With no nearby markets to consume the gas and no means to get the gas to distant markets, vast quantities of natural gas associated with crude oil production were vented to the atmosphere" (Nersesian, 2007: 225).

Today it can be observed that natural gas usage is increasing in areas such as generating electricity, transportation and heating households. The liquefied petroleum gas (LPG) used in households for heating and cooking constitutes of propane and butane which are stored in pressurized in liquid state apart from natural gas. Another hydrocarbon of natural gas, methane is used to generate electricity and heat buildings. Automobiles were using oil as fuel however; consumers are now installing engineered gears to use natural gas a fuel whereas car companies are producing cars that run with natural gas. Burning natural gas for transportation is cheaper than that of oil besides; "natural gas vehicles emit up to 93% fewer hydrocarbons, 90% less carbon monoxide, 90% fewer toxic emissions" (Raven et.al., 2010: 243). Furthermore houses that were burning oil for heating purposes are nowadays reverting to natural gas engines. The convenience and popularity of natural gas is believed to continue due to one fact that it is cheaper moreover, in terms of generating electricity; a power generator fueled with natural gas is more efficient and less costly to construct one with contrast to an electricity generator facility fueled by oil.

In terms of environmental effects, even though all fossil fuels generate carbon dioxide when processed (Table 1-5), natural gas has the least negative drawback and does not pollute the atmosphere as much as coal and oil. This is due to fact that natural gas does not obtain as much hydrogen as coal or oil thus the lower the hydrogen the lesser carbon dioxide emission. Moreover the technology used in generating electricity plays a crucial role in emissions.

Table 1-5 Carbon dioxide emissions

Method of Production	Emissions (g/kWh)
Coal	860-1290
Oil	700-800
Gas	480-780
Nuclear	4-18
Wind	11-75
Solar photovoltaic	30-280
Biomass	0-116

Source: Ngo, 2008: 21

Furthermore, aside from being more expensive to transport from the source to the consumer natural gas, much like oil, bears serious risks and requires somewhat more complicated technology. Gas can be transported in liquid form at a temperature of -160 Celsius withal considering the fact that around 20% of gas worldwide is transported in this form a special technological vehicle is necessary to contain and preserve natural gas in its crude form. Specially built liquid natural gas container vehicle for about 280 m long obtains around 130,000 m^3 of liquid natural gas (LNG) and it is a fact that accidents could occur just as they do with oil tankers. "The energy contained in such a vehicle represents more than 40 times that liberated by the explosion of the atom bomb over Hiroshima in 1945" (Ngo, 2008). Automobiles those which run with LPG also bear the risk ergo commonly they are not authorized to park underground garages due to pressure and the serious ramifications of a potential explosion.

World leader in natural gas reserves Table 1-6, is Russia with 25% followed by Iran with 15%, Qatar 13%, Turkmenistan 4%, Saudi Arabia 4% and the US 3% of the overall world reserves. From a wider perspective, around 60% of the natural gas reserves lay in Middle East and Eurasia.

Table 1-6 World natural gas reserves 2010

Country	Reserves (trillion cubic feet)	Percent of World Total
World	6,609	100,0
Top 20 Countries	6,003	90,8
Russia	1,680	25,4
Iran	1,046	15,8
Qatar	899	13,6
Turkmenistan	265	4,0
Saudi Arabia	263	4,0
United States	245	3,7
United Arab Emirates	210	3,2
Nigeria	185	2,8
Venezuela	176	2,7
Algeria	159	2,4
Iraq	112	1,7
Australia	110	1,7
China	107	1,6
Indonesia	106	1,6
Kazakhstan	85	1,3
Malaysia	83	1,3
Norway	82	1,2
Uzbekistan	65	1,0
Kuwait	63	1,0
Canada	62	0,9
Rest of the World	606	9,2

Source: EIA, 2010, p.57

1.1.2. Nuclear Power

In 1896, Antione Henri Becquerel discovered that uranium was releasing invisible rays of energy henceforth known as radiation. Marie Curie, in the same year, discovered that the so called radiations were originating from uranium itself, and she gave the name ‘radioactivity’ to this phenomenon. In 1905 Albert Einstein first asserted that mass and energy are related in his groundbreaking equation $E = mc^2$, in which energy (E) is equal to mass (m) times the speed of light (c = 300,000 km/sec) squared. (Raven et.al., 2010)

Table 1-7 Nuclear plants in operation

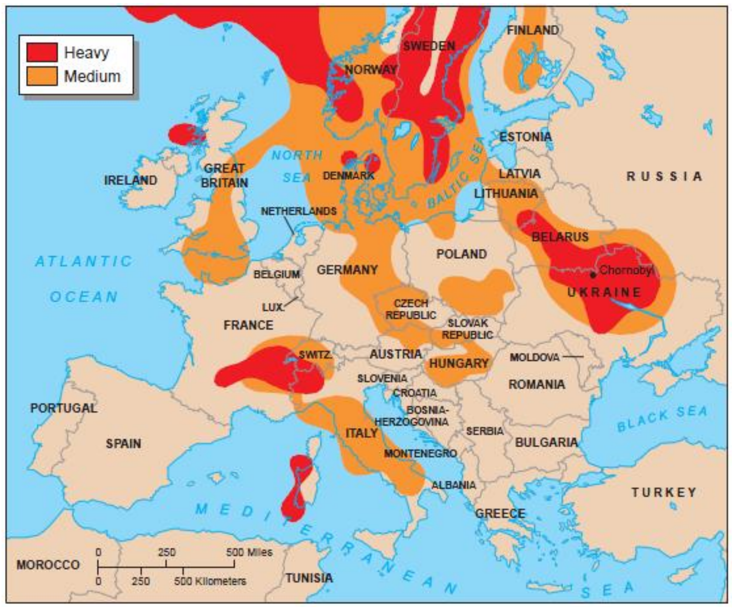
Country	Number of Reactors
United States	104
France	59
Japan	54
United Kingdom	33
Russian Federation	30
Germany	19
Republic of Korea	18
Canada	14
India	14
Ukraine	13
Rest of the World	83
Total	441

Source: OECD, 2003, p.10

Researches in nuclear energy have been on the rise following the aforementioned developments. Sir James Chadwick was the pioneer to discover the neutron and successfully bombard the uranium atoms with neutrons and create the first nuclear fission and generate energy which led in 1943 to the first controlled chain reaction was put in practice. Furthermore in 1945 it was first used as an atomic weapon during the World War II which also finalized the war. First electricity generation from a nuclear reaction was in 1951 over and above in such a short time span nuclear research has improved vastly from the discovery of the neutron to generating electricity and weaponry.

The world’s first commercial nuclear power plant opened at Calder Hall in England in 1956; the first plant in the United States opened at Shippingport, Pennsylvania, in 1957. As of 2003, there exist 441 (OECD, 2003) operating nuclear power reactors (Table 1-7) generating around 6 percent of the worlds energy demand and supplying 17 percent of the electricity consumption. In terms of energy content comparison in 1 tonnes, wood bears 14 GJ, coal 29 GJ, oil 42 GJ, LNG 46GJ and uranium 630 000 GJ. For a better understanding according to the corresponding information, energy generated by 1 kg of uranium is equal to 14 000 kg of LNG.

Figure 1-6 The Radioactive Fallout from Chernobyl



Source: Raven et.al., 2010, p.266

Although it is more efficient use small amount of fuel and obtain large amount of energy nuclear energy power plants number one challenge is the high cost of construction and a considerable amount of cost is also incurred after the plant ceased to operate (mostly the decommissioning and nuclear waste disposal costs). Aside from the construction and post-operation costs, because nuclear power plants are mainly high technology investment thus they require long time of planning and constructing.

Previously in Table 1-5 it can be clearly acknowledged that nuclear reactions as a method of generating electricity deploys the least amount of CO_2 emissions not only amongst the fossil fuels but also among some renewable resources. Nevertheless with the nuclear reaction in consideration, it is mostly not the carbon gas emission rather it is the waste disposal and radioactive leaks. In 1979 the Three Mile Island Power Reactor in the United States, experienced a 50 percent meltdown of the reactor core. Although it had been only the 50 percent still it took 12 years and an amount of $1 billion to repair and reopen the reactor. Moreover, it was not the most significant disaster yet, because in 1986 the Chernobyl nuclear power plant located in the formerly Soviet Union, today Ukraine had encountered a massive destruction with explosions. The first impact of this disaster was the large amounts of radioactive materials emitted in the atmosphere endangering not only the wild life and nature but also the people living in the vicinity (Figure 1-6). "Farmland and forest contamination led to reduced agricultural production. Inhabitants in parts of Ukraine still cannot drink the water or consume local produce." (Raven et.al., 2010: 265) The one and may be the most significant drawback of the Chernobyl incident was the effects on the human life both then and the generations to come. "Death quickly followed for those in contact with the radioactive debris or caught in the radioactive cloud close by the plant" (Nersesian, 2007: 280). Most of those who have encountered the fallout today suffer from various types of cancer and immune system abnormalities.

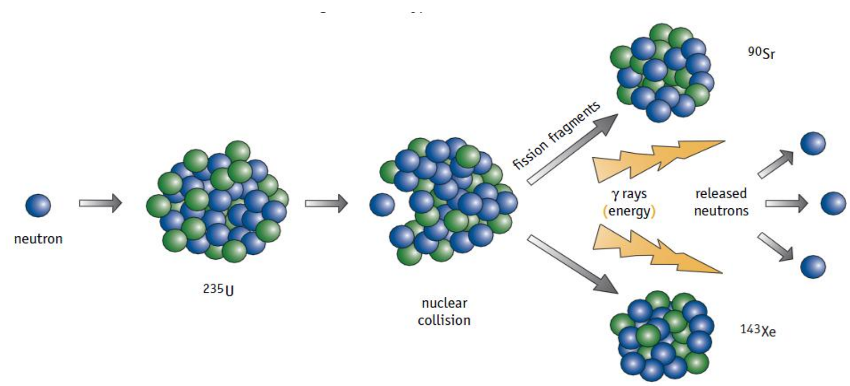
Radioactive wastes are categorized in two as low-level radioactive waste (LLW), intermediate-level radioactive waste (ILW) and high-level radioactive waste (HLW). Items that are defected with short lived radioactive elements are considered as LLW which are produced by nuclear plants, research facilities of universities, hospitals those have nuclear treatment facilities. Waste produced more generally at the industrial level are classified as ILW. The nuclear waste generated out of the nuclear fission process; spent fuel rods and assemblies, is categorized as HLW and must be contained in specific storage units that require cooling shield. Overall, 13.000 metric tons of HLW is generated every year around the world. These wastes produce serious amount of heat, are extremely toxic to organisms, furthermore preserve their toxicity for thousands of years. Nevertheless when compared to other types of fuel in terms of waste generated per unit of energy, nuclear energy stands the least such that due to its high density of energy, nuclear energy generates low volume of waste per unit of energy. Besides, when considering the overall amount of waste produced in a year for example in the EU, the industrial waste is around 1000 million cubic meters while HLW is only 500 cubic meter (OECD, 2003).

Uranium is the ore element of the nuclear power generation process which is a non-renewable resource as well as other fossil fuels. Energy is generated when change occurs in the chemical bonds that hold the atoms together, in this case the uranium atoms. World leader in uranium reserves is Australia (20.4%), followed by Kazakhstan (18,2%), United States (10,6%) and Canada (9,9%). Uranium U_{235} must be refined and processed in order to increase its concentration to a min 3% which is known as enrichment. In terms of generating energy via nuclear process it is the nuclei of atoms that are altered. There are two different nuclear reactions that release energy and change the chemical bonds that hold the atoms together: Nuclear Fission and Nuclear Fusion.

1.1.2.1. Nuclear Fission

"When the nucleus of any such element is impacted by a neutron which it absorbs, it can fission or split into two fragments, releasing at the same time two or three neutrons and energy (Figure 1-7)" (OECD, 2003: 13). Following the fission, the split neutrons start to collide with the other atoms and converting the motion energy into heat which consequently is used to generate electricity. The operating nuclear power plants of today use the nuclear fission reaction in order to generate electricity due to the fact that with the level of technology nuclear fission is more practical. Nevertheless with the improvement of the nuclear research and technology, the future of nuclear energy is expected to lay in nuclear fusion.

Figure 1-7 Fission Reaction

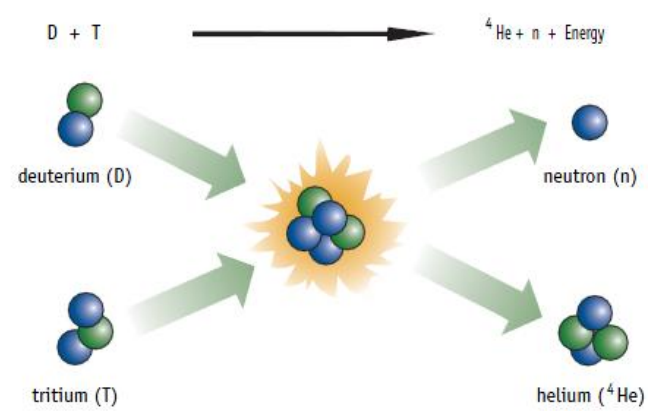


Source: OECD, 2003, p.14

1.1.2.1. Nuclear Fusion

“Whereas nuclear fission involves the splitting of a heavy atomic nucleus and a consequent release of energy, nuclear fusion is a process of combining light nuclei to form massive nuclei with the release of energy (Figure 1-8)” (OECD, 2003: 20). This kind of reaction occurs in the core of the sun at extremely high temperatures viz converting hydrogen into helium thus providing energy.

Figure 1-8 Nuclear Fusion Reaction



Source: OECD, 2003, p.20

Providing that the nuclear fusion becomes practicable it would be much more beneficial in terms of generating energy with an unlimited supply of fuel such that deuterium is available in water and tritium is processed from lithium, which are abundantly found in nature. Moreover the waste generated is far more less than nuclear fission. Considerable amount of research is being upheld around the world in several research facilities such as EU's Joint European Torus (JET), Princeton Physics Laboratory and JT-60U Tokamak at Japanese Atomic Energy Research Institute.

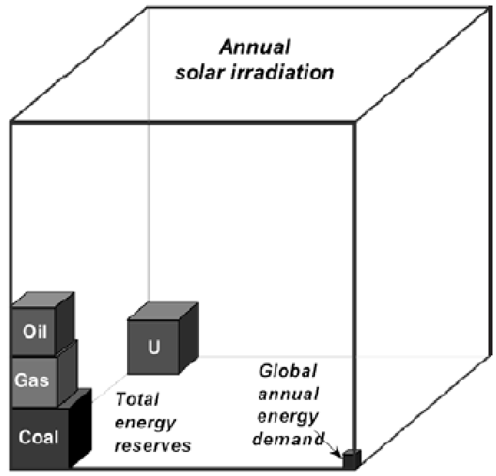
1.2. Renewable Resources

Renewable energy resources are basically those which are inexhaustible and can be generated within the natural cycle in a shorter period than that of fossil resources. Most common renewable resources such as solar energy, hydropower, wind power and some not quite so convenient are biomass and wave and tidal power. There are three origins for the corresponding renewable resources which are solar radiation, planetary energy and geothermal energy. Although we categorize the corresponding sources as renewable it is the due to the fact that they have a longer time sustainability in contrast to fossil fuels however, in the very long term even the sun's radiant energy is expected to diminish and maybe deplete viz none of the current energy resources are completely inexhaustible and sustainable (Evans, 2007). One of the main factors that make the renewable energy resources indispensable is the low amount of CO_2 emission.

1.2.1. Solar Energy

Sun is the largest energy source in the world acting as a fusion reactor transforming hydrogen into helium thus generating energy. The annual energy provided by the sun is $3.9*10^{24}$ J = $1.08*10^{18}$ kWh which is nearly ten thousand times of the annual energy demand and by far the most abundant energy reserve on earth. Figure 1-9 depicts the annual solar irradiation exceed several times the global energy demand and all fossil fuel reserves. (Quaschning, 2005) Solar energy circulates all around the world. In this regard unlike the fossil fuels solar energy does not give rise to conflicts, all it requires is to collect it.

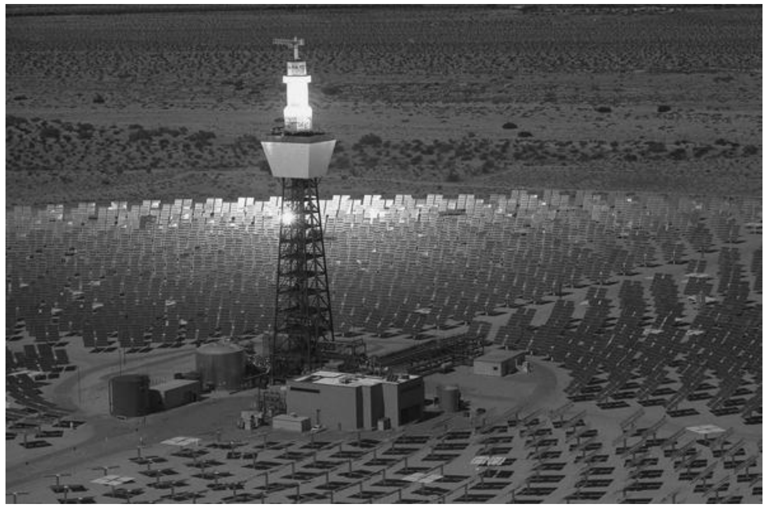
Figure 1-9 Energy Cubes



Source: Quaschning, 2005, p.22

The amount of solar energy varies during weather and season shifts hence in summer the solar radiation received would be higher while it will be lower in the winter. Furthermore, the regions longitude and latitude also plays a role on the amount of solar radiation it receives such that regions closer to the equator are more likely to receive a higher solar radiation than that of North or South Poles. Solar radiation also differs according to the time of the day; at noon when the sun is high in the sky it would be more intense than at dawn when it is low in the sky. Although there are peaks and low points in receiving solar radiation it is not possible to use the full intensity of the sun's solar energy circulating around the world because "30% is reflected back into space, 45% is absorbed, converted into heat and returned to space in the form of infrared radiation, while the remaining (25%) contributes to evaporation (22%), wind kinetic energy (2%) and photosynthesis (0.06%)" (Ngo, 2008: 36).

Figure 1-10 Concentrating solar power plant



Source: Evans, 2007, p.86

In order to harness and use the solar energy to generate electricity specific technologies and constructions are required such as, solar photovoltaic systems (PV), concentrated solar power and, for solar heating and cooling systems, solar thermal energy systems are required. In the case of solar thermal energy systems the idea is to use the solar energy directly as a source for heating or electricity generating in residential and commercial buildings. Architecturally designed buildings enable to absorb sunlight during the daytime as much as possible and then using this energy to cool the building which normally was provided by burning fossil fuels, natural gas or oil. “Active solar heating uses ‘‘solar collectors,’’ usually mounted on rooftops for residential buildings, to heat water, or another fluid which is then circulated to other parts of the building” (Evans, 2007: 84). Concentrating solar collectors are used to generate electricity which uses one or more reflecting mirrors to revert a high intense beam of solar energy to a focal point in order to generate a high temperature heat (Figure 1-10).

Figure 1-11 Windmills

Source: EREC, 2010, p.96

The last application of solar energy; "solar photovoltaic systems convert direct and diffused solar radiation into electricity through a photovoltaic process using semi-conductor devices" (IEA, 2010). The most significant characteristic of PV's are that they are most convenient to use anywhere the sun shines and there is an inverse relation between the intensity of the sunshine and per kWh of electricity produced; such that the more sun absorbed by the semiconductor the more electricity it will generate thus the lower the cost will be. There are but two drawbacks of this method of electricity generation are; high per unit cost with today's technology and unable to perform at night. Although with the improving technology the cost per unit is dropping it is still far from reaching the cost to compete with fossil fuels. Overall these applications provide benefits; reducing the dependency on fossil fuels, diversifying energy supply, decreasing CO_2 emission costs and air pollution.

In terms of using thermal solar energy to generate electricity China is the leader with generating 22.4GW, followed by the United States with 17,5GW, Japan with 8,4GW, Turkey with 5,7GW and Germany 3,0GW.

1.2.2. Wind Power

Perhaps the first of all the renewable energy systems people learned to harness the natural power of the wind; windmills in order to crush the grain and sailboats for travelling on the seas and oceans. Today the same concept with the help of improved technology is used to harness the power of wind to generate electricity.

Table 1-8 Top ten countries in installed wind power capacity

Country	MW	%
Germany	22247	23,6
United States	16818	17,9
Spain	15145	16,1
India	8000	8,5
China	6050	6,4
Denmark	3125	3,3
Italy	2726	2,9
France	2454	2,6
Unites Kingdom	2389	2,5
Portugal	2150	2,3
Rest of the World	13018	13,8
Total top ten	81104	86,2
Global Total	94122	2,4

Source: Aswathanarayana, Harikrishnan and Thayyib Sahini, 2010, p.14

Although the first windmills require significant amount of wind to operate, modern turbine technologies enable the windmills to generate electricity with low or high wind speed, nevertheless they require the wind to be at a minimum speed of 18-25 km/hr. The first wind turbine for the purpose of generating electricity was established in 1939 Vermont, US with the capacity of 1,25MW constituted a cornerstone in the improvement of windmill technology. (EREC, 2010) “Since 2001, wind power has been growing at a phenomenal rate of 20% to 30% per annum. Wind power (2 016 GW) is expected to provide 12% of the global electricity by 2050" (Aswathanarayana et.al., 2010: 13).

On the other hand, windmill technology is a capital intensive industry such that 70 to 80% of the investment is for the production while it is around 40 to 60% for fossil fuel power stations, thus price of capital is a very important factor for the cost of wind generated electricity. Currently the capital cost of an above average windmill is $1000-2000 per MWe generated. Nevertheless today there has been a tendency towards wind power due in part to low CO_2 emissions and improved technologies that have enabled cost deduction per unit of production. Withal constructing the windmills in a specific location known as, wind farms have also increased the efficiency and decreased the costs by creating economies of scale. (Evans, 2007) Around 40 countries have invested in windmills and Germany with a production of 22,247MW is the leader (Table 1-8).

1.2.3. Ocean Energy

Ocean is one of the major sources of renewable energy with an estimated potential of 100,000TWh per annum. Two ways to harness this potential energy is via waves and tides.

1.2.3.1. Tidal Power

"Tidal energy conversion techniques exploit the natural rise and fall of the level of the oceans; caused principally by the interaction of the gravitational fields in the solar system" (EREC, 2010: 191). The energy restored in tides can be harnessed by tidal barrages which operate in such a way that during the ebb tide penstocks are opened to release the water and spin the turbines to generate electricity. Likewise, during the flood tide water is allowed to fill in the barrage. Consequently this process indicates that electricity can be generated according to the number of tides. Today there are only a few modern tidal barrages operating among them the biggest and most commonly known is situated in France, Rance power plant which has a power generation capacity of 240MW. Main drawbacks of tidal barrages are that they are dependent on the ebb and flow which is not very common in every region and it is costly to construct and operate tidal power plants.

1.2.3.2. Wave Power

As well as tides, significant amount of energy is contained in the ocean waves such that “the estimated wave electricity potential is 300 TWh/yr” (Aswathanarayana et.al., 2010: 50). Aside from the estimated numbers, the damage that is caused to the shorelines by waves are irrefutable evidence demonstrating the power of waves. “Waves are caused by wind and their enormous energy potential can be tapped by using hydraulic or mechanical means to translate the up-and down motion to rotate a generator” (Nersesian, 2007: 324). Nevertheless today, the systems and machinery to harness the wave power and generate electricity are not adequate enough and expensive to maintain market production yet research and development is pursued in countries which have coasts. Among these coastal countries the largest share of technologies under development is in the UK, followed by the US, Canada and Norway. The idea is to extract energy as waves hit the shorelines which are considered as on-shore systems and, off-shore systems which use the wave in a distance from the shore. Wave energy is partly dependent on the wind thus it does not follow a strict pattern to indicate that there will be standard amount of electricity generation. (Danny Harvey, 2010)

1.2.4. Geothermal

Geothermal energy is another renewable energy as well as tidal energy that do not solely depend on the sun as the source of its energy. “Geothermal energy is the heat from the earth core. Earth’s temperature increases with depth, under a gradient of 2–3°C/100m. The total heat flux from the earth’s interior provides us with; an abundant, non-polluting, almost infinite source of clean and renewable energy” (EREC, 2010: 208). From time to time volcanic eruptions around the world demonstrate the scale of this renewable energy restored in earth’s interior. Earth’s core is has a diameter of 6900km in which the maximum temperature is nearly 6500°C thus in order to harvest this energy different technologies are required. Amongst countries that use these technologies the leader is the United States with an installed capacity of 2,228MW geothermal energy, followed by New Zealand (437MW), Iceland (170MW), El Salvador (161MW), Costa Rica (143MW) and the overall capacity of geothermal power plants around the world is 10GW in 2007, generating 56 TWh/yr of electricity. (Aswathanarayana et.al., 2010)

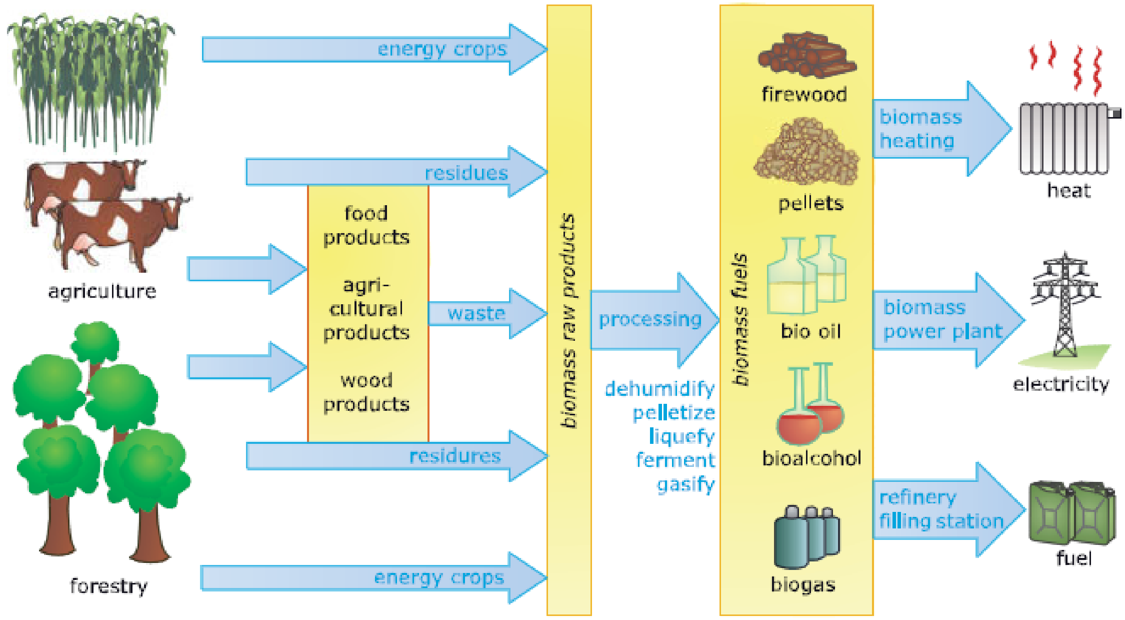
Although since ancient times geothermal energy in the form of thermal baths and hot springs was used by people yet with the improvement of technology and need for alternative clean source of energy then it is used to generate electricity. High density geothermal power is used to generate electricity while lower temperature geothermal sources can be used for heating purposes in several areas ranging from domestic houses to animal shelters.

Geothermal energy has no carbon gas emissions, estimated reserves are nearly 100 thousand times of the world's overall energy use, there are no variations in production as in other types of renewable energies and the production costs are low compared to other sources. Nevertheless, the construction and drilling viz initial costs are high ranging from \$100.000 to \$250.000 per well besides due to fact that harnessing geothermal power requires drilling into the earth's core, it may alter the pressure which could lead to landslides and mini earthquakes. Overall, "geothermal energy is a clean, reliable and base-load energy (as it is available all year), that allows economical savings in terms of fuel imports avoided and can create jobs in local communities" (EREC, 2010: 210).

1.2.5. Biomass

"Biomass is the energy stored in living matter such as vegetation. Using biomass to produce energy is an indirect way of using solar energy" (Ngo, 2008: 44). Biomass refers to all forms of life, dead, organic, decaying metabolism products. Plants produce biomass through photosynthesis, with the energy of the sun and converting CO_2 and H_2O into carbohydrates and oxygen presented as; $n(CO_2 + H_2O) \xrightarrow{hv} (CH_2O)_n + nO_2$. In this regard plants are crucial both in terms of generating the oxygen and the biomass CH_2O carbohydrates which all the living things require for survival.

Figure 1-12 Possibilities for biomass use



Source: (Quaschning, 2010, p.240)

Most likely the first source of energy used by people is the biomass energy in the form of lumbering, wood gathering and generating heat for food cooking or space cooling. Even though wood gathering seems to be somewhat primitive, it has been the stepping stone for humans to develop one step ahead and today despite the fact that more efficient fuel sources exist the use of biomass energy has grown beyond from burning wood. "Combustion of wood-waste to generate steam in pulp and paper mills, the use of ''landfill gas'' from municipal solid waste (MSW) for electrical power generation, and the production of ''biodiesel'' fuel and ethanol from corn and grain crops" (Evans, 2007: 100) are among some examples of the use of biomass. As it can be seen from the Figure 1-12 the biomass raw products encounters with processes such as; drying, compressing, fermenting in alcohol, converting into biogas, pelletizing or converting into fuel in chemical plants. Only after these alterations can the biomass raw product could be used as a source for electricity, heating or fuel. For example in order to produce biodiesel, vegetable oil and animal fat are used as raw material.

Figure 1-13 Historic watermill

Source: Quaschning, 2010, p.191

Figure 1-12 demonstrates the possible uses of the biomass ranging from heating to electricity generation. With the need for alternative energy resources and the necessity to decrease the CO_2 emissions biomass holds a crucial role in resolving both problem. Through photosynthesis plants decrease the CO_2 and in the process produce biomass which can be used as biofuels to generate electricity.

1.2.6. Hydropower

Around 70 percent of the world's surface is covered with water, a resource that has been the core element for the survival of all living things. As presented in the previous part, plants use water (H_2O) in order to conduct photosynthesis and pursue its existence as well as animals and humans drink water which can be replaced with nothing. Nevertheless, apart from its direct consumption, the power restored in water has been used for centuries such as watermills which operate with the basic idea that govern the wind mills yet in this case the source that spins the mill is water.

Today with the same concept water power is utilized to generate electricity via transforming the kinetic energy and pressure of the water movement through rivers, dams, canals and streams. “The rushing water drives a turbine, which converts the water’s pressure and motion into mechanical energy, converted into electricity by a generator” (EREC, 2010: 170). Mainly the idea is to use the water from high elevations flowing to reach the sea level which can be done by building dams.

Today around 90 percent of the overall renewable energy and 19 percent of the world’s electricity is attained from hydropower plants. The leader in terms of hydropower output is Canada with 345TWh/yr followed by Brazil (288TWh/yr), USA (264 TWh/yr) and China (231 TWh/yr). Hydropower plants have high initial construction costs nevertheless operation costs are low. “Although the capital costs of hydroelectric power plants are usually higher than those for thermal power stations, hydroelectric plants normally have a much longer life expectancy, and with no fuel costs, provide a low-cost source of electricity” (Evans, 2007: 104). Although hydropower plants provide low-cost source of electricity there are problems which are summarized in Table 1-9.

Table 1-9 Reasons and Problems for Building Dams

Reasons to Build Dams	*Problems with Dams*
Electrical power	Ecological disruption downstream
Mechanical power	• Sediment stopped in dam
Irrigation	• Water source diverted
Navigation	• Fish migration halted at dam
Flood control	Ecological disruption in reservoir
Commercial fishing	• Habitat flooded
Recreation	• Sediment buildup
• Fishing	• Pollution if toxic materials are submerged
• Swimming	Displacement of people
• Boating	Loss of cultural resources
	Catastrophic failure
	Disease
	Seismisity
	Evaporation from reservoir

Source: (Raven et.al., 2010, p.287)

PART TWO

COUNTRY PROFILES AND RESERVES

2. Country Energy Profiles and Reserves

The last decade of the twentieth century has been marked in the history as the time of changing equilibriums in every aspect from political, sociological to economical. Perhaps the most effective change occurred with the broad trade liberalization along with enhancing global markets and financial systems. In this era of economical transformation, the newly established post-socialist states were those who have faced unprecedented challenges. Although centrally planned socialist economies, constituting of five year plans have provided high growth rates "in the 1950s and 1960s, when national economies were relatively small, domestic raw materials could be fully used (with some imports from Former Soviet Union (FSU)) and surplus labour could be released from agriculture" (Turnock, 2005: 26) it was not enough in a time of economical liberalization.

Although declining growth rates disclosed pressures towards a reform, the transition have started following the collapse of the FSU, communism along with it, and "without the FSU's power to impose stability the future of the region becomes uncertain. However, the former '[state-] socialist countries' have a common interest in negotiating the transition to a market economy and integrating more closely with Western Europe and the EU" (Turnock, 2005: 3). In this regard the political shift enabled radical economic transformations from central planning to market economy. Along with the shift in the economical structure, transition economies energy profile have also been altered in a way that between 1990 and 2007 (Table 2-1), total primary energy supply (TPES) have decreased 25 percent, along with a 31 percent decrease in the CO_2 emission however their GDP have increased 24 percent in the corresponding years. Even though with the realized growth the expectation would be that with technological improvement the demanded thus consumed energy would be higher along with the carbon emissions yet, "planned economies tend to be more and market economies less energy intensive, which is defined as energy consumed per unit of economic output. Although western energy use may be physically and environmentally excessive, its economic efficiency is far higher than in the transition economies" (Chandler, 2000: 7). The overall inference is that transition economies use much higher amounts of energy than that of contemporary

Table 2-1 Energy Indicators of Economies in Transition

	1990	1995	2000	2004	2005	2006	2007	% change 90-07
CO_2 Sectoral Approach (Mt of CO_2)	3 970.8	2 828.6	2 559.7	2 616.5	2 617.1	2 696.7	2 702.5	-31.9%
CO_2 Reference Approach (Mt of CO_2)	4 137.8	2 889.2	2 604.4	2 677.8	2 680.4	2 746.9	2 726.1	-34.1%
TPES (PJ)	63 007	45 943	42 918	45 280	45 941	46 910	46 905	-25.6%
TPES (Mtoe)	1 504.9	1 097.3	1 025.1	1 081.5	1 097.3	1 120.4	1 120.3	-25.6%
GDP (billion 2000 US$)	838.5	628.3	712.9	868.0	914.5	978.2	1 046.7	24.8%
GDP PPP (billion 2000 US$)	3 007.8	2 110.7	2 333.0	2 887.4	3 044.0	3 260.1	3 495.2	16.2%
Population (millions)	321.1	319.5	313.9	308.0	306.8	305.6	304.3	-5.2%
CO_2 / TPES (t CO_2 per TJ)	63.0	61.6	59.6	57.8	57.0	57.5	57.6	-8.6%
CO_2 / GDP (kg CO_2 per 2000 US$)	4.74	4.50	3.59	3.01	2.86	2.76	2.58	-45.5%
CO_2 / GDP PPP (kg CO_2 per 2000 US$)	1.32	1.34	1.10	0.91	0.86	0.83	0.77	-41.4%
CO_2 / population (t CO_2 per capita)	12.37	8.85	8.16	8.50	8.53	8.82	8.88	-28.2%

Ratios are based on the Sectoral Approach.

Source: IEA, 2009, p.87

economies, thus even though the economies experience growth their energy supply and CO_2 decreases correspondingly. Another inference would be that the transition economies abundant source of energy were mainly fossil fuels yet mostly coal which emits the highest amount of CO_2 thus along with the economies, their source of energies have also been changed towards less carbon emitting sources.

This section will dwell on the energy and economic profiles of the EU member countries of CEE and the EU candidate countries. The main characteristics of the CEE countries lay in the fact that these are transition economies which have undergone significant structural changes ranging from political to economical. Mainly transition economies include 26 nations of which 15 were established from the dissolved FSU; Armenia, Azerbaijan, Belarus, *Estonia*, Georgia, Kazakhstan, Kyrgyzstan, *Latvia*, *Lithuania*, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan; 11 countries in CEE *Bulgaria*, the *Czech Republic*, *Hungary, Poland, Romania*, *Slovakia*, Bosnia and Herzegovina, *Croatia*, Kosovo, *Macedonia*, Montenegro, Serbia and

Slovenia (Chandler, 2000). The countries in italic along with Turkey are in the context of this study as CEE, new EU member and candidate countries.

2.1.1. EU Members

2.1.1.1. Estonia

Estonia is an Eastern European country bordering the Baltic Sea and Gulf of Finland situated between Latvia and Russia. As of 2009 Estonia has a population of 1,34 million and a GDP of $19,083 billion (current US$). Total energy production in 2008 is around 4,22Mtoe, electricity consumption 8,51TWh and the corresponding CO_2 17Mt.

Table 2-2 Energy Balance for Estonia (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	3462	0	0	0	0	2	11	741	0	0	4217
Imports	86	0	1133	770	0	0	0	0	118	0	2107
Exports	-62	-273	0	0	0	0	0	-104	-199	0	-637
International Marine Bunkers**	0	0	-248	0	0	0	0	0	0	0	-248
International Aviation Bunkers**	0	0	-28	0	0	0	0	0	0	0	-28
Stock Changes	-53	0	44	0	0	0	0	-5	0	0	-14
TPES	**3433**	**-273**	**902**	**770**	**0**	**2**	**11**	**632**	**-81**	**0**	**5398**

Source: IEA, 2011a

Although Estonia is the only country to be primarily dependent on oil shale[1] as a source of energy, overall her energy consumption is highly dependent on imports (Table 2-2). Estonia has no oil production thus all of the oil products are imported as well as gas which is a major challenge in front of Estonia's energy policies in terms of energy security, and source diversification.

In 2004 Estonia has become the a full member to the EU and a part of the EU-8 countries namely The Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the

[1]A general term applied to a group of fine black to dark brown shale's rich enough in bituminous material (kerogen) to yield oil upon heating in a retort. Such a fuel is called shale oil, a form of unconventional oil.

Slovak Republic and Slovenia which have also joined the EU simultaneously. One of the major proceeds of the membership to EU for Estonia has been that the existing W directives concerning energy security, nuclear safety, Internal Energy Market (IEM) and the Emissions Trading Scheme (ETS) are now applicable for Estonia as well. "EU-8 plays an important transit role, as 27% of natural gas supply and about 10% of crude oil supply of the first 15 EU members (EU-15)[2] transits this area from the Commonwealth of Independent States[3] (CIS)" (IEA, 2011b).

2.1.1.2. Latvia

Latvia is an Eastern European country bordering the Baltic Sea, situated between Estonia and Lithuania. As of 2009 Latvia has a population of 2,27 million and a GDP of $26,19 billion (current US$). Total energy production in 2008 is 1,79Mtoe, electricity consumption 7,00TWh and the corresponding CO_2 emission is 7,91Mt. As well as

Table 2-3 Energy Balance for Latvia (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	3	0	0	0	0	267	5	1514	0	0	1789
Imports	107	23	1844	1095	0	0	0	11	399	0	3479
Exports	-2	0	-132	0	0	0	0	-387	-183	0	-704
International Marine Bunkers**	0	0	-203	0	0	0	0	0	0	0	-203
International Aviation Bunkers**	0	0	-97	0	0	0	0	0	0	0	-97
Stock Changes	0	0	10	238	0	0	0	-28	0	0	220
TPES	**107**	**23**	**1422**	**1333**	**0**	**267**	**5**	**1110**	**217**	**0**	**4484**

Source: IEA, 2011c

Estonia, Latvia is also highly dependent on energy imports (Table 2-3) viz she has no domestic oil, gas production or refineries. Most of the domestic production relies on hydropower plants and combustible renewable and waste. Nevertheless being a part of

[2] EU-15; Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

[3] Regional organization whose members were Former Soviet Republics

the EU-8, Latvia plays a crucial role in transiting the Russian oil to the EU-15 moreover; the same policies and advantages by virtue of being an EU member referred to in the previous country profile are also valid for Latvia.

2.1.1.3. Lithuania

Lithuania is an Eastern European country bordering the Baltic Sea, situated between Latvia and Russia. As of 2009 Lithuania has a population of 12,47 million and a GDP of $37,20 billion (current US$). Total energy production in 2008 is 3,85Mtoe,

Table 2-4 Energy Balance for Lithuania (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	19	129	0	0	2623	35	12	836	0	200	3853
Imports	243	9461	541	2499	0	0	0	75	486	0	13305
Exports	-7	-130	-7150	0	0	0	0	-102	-568	0	-7956
International Marine Bunkers**	0	0	-89	0	0	0	0	0	0	0	-89
International Aviation Bunkers**	0	0	-76	0	0	0	0	0	0	0	-76
Stock Changes	-36	122	-36	96	0	0	0	-6	0	0	140
TPES	**219**	**9582**	**-6810**	**2595**	**2623**	**35**	**12**	**803**	**-82**	**200**	**9177**

Source: IEA, 2011d

electricity consumption 11,95TWh and the corresponding CO_2 emission is 14,24Mt. Lithuania, apart from having small reserves of oil and gas, is also highly dependent on energy imports (Table 2-4) viz her energy is dependent on imports. Lithuania is the only Baltic state operating an oil refinery.

Also from the Table 2-4 it can be observed that significant amount of the domestic energy production of Lithuania generates from nuclear power. There were two nuclear power plants in Ignalina, one of which was decommissioned due to the accession to the EU in 2004 and the second one in 2009 with the alignment to the EU Accession Treaty. Although Table 2-4 indicates that Lithuania obtains nuclear power production, the data is up to 2008 which is prior to the decommissioning of the last nuclear power plant in 2009. Nevertheless "taking into consideration energy security issues and the possibility of using the existing infrastructure at Ignalina, new nuclear power plant capacity will be commissioned in Lithuania" (WEC, 2010: 275).

2.1.1.4. Poland

Poland is a Central European country bordering the Baltic Sea, situated east of Germany. As of 2009 Poland has a population of 38,12 million and a GDP of $430,07 billion (current US$). Total energy production in 2008 is 71,39Mtoe, electricity consumption 142,27TWh and the corresponding CO_2 emission is 298,69Mt. As Table 2-5 indicates, coal and peat represents a significant amount of energy production with nearly 61 Mtoe of all 71 Mtoe. When considering the fact that Poland being amongst the top ten coal producers in the world, it is logical for her energy production to be mostly

Table 2-5 Energy Balance for Poland (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	60911	788	0	3689	0	185	86	5735	0	0	71394
Imports	6494	22106	5853	9154	0	0	0	157	729	0	44494
Exports	-10069	-252	-3017	-32	0	0	0	0	-834	0	-14205
International Marine Bunkers**	0	0	-272	0	0	0	0	0	0	0	-272
International Aviation Bunkers**	0	0	-536	0	0	0	0	0	0	0	-536
Stock Changes	-2590	-263	129	-268	0	0	0	-1	0	0	-2993
TPES	**54745**	**22379**	**2156**	**12543**	**0**	**185**	**86**	**5891**	**-105**	**0**	**97881**

Source: IEA, 2011e

dependent on coal. Besides, "apart from Russia, Poland is the only world-class coal exporter in Europe" (WEC, 2010: 33). Nevertheless, along with the economic transition after the collapse of the Soviet Union, Polish energy profile has been changed. Despite the fact that Poland is a major coal producer the reality is that output of coal has been decreasing following the collapse of the FSU.

Renewable energy resources constitute the second largest domestic source of energy. "Wind turbines have been installed, mostly in the northern coastal region but also throughout the western and central parts of the country and the Carpathians, ranging from less than 1 MW capacity to many tens of MW" (WEC, 2010: 533). As of 2008 installed wind capacity in Poland reached to a level of 482 MW and the planned energy capacity is to reach by the end of 2010 is 2 000 MW.

On the other hand Poland is highly dependent on Russian oil while her domestic oil production only constitutes a relatively low amount with contrast to the overall electricity production. High dependence on oil, especially on one exporter is one of the most significant challenges of Poland's energy security and diversification of sources.

2.1.1.5. Czech Republic

Czech Republic is a Central European country situated between Germany, Poland, Slovenia and Austria. As of 2009 Czech Republic has a population of 18,17 million and a GDP of $190,27billion (current US$). Total energy production in 2008 is 32.82 Mtoe, electricity consumption 67,39 TWh and the corresponding CO_2 emission is

Table 2-6 Energy Balance for Czech Republic (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	22785	306	0	160	6943	174	27	2400	0	24	32819
Imports	2036	8242	2740	7813	0	0	0	101	733	0	21665
Exports	-5131	-20	-1332	-790	0	0	0	-299	-1719	-3	-9294
International Marine Bunkers**	0	0	0	0	0	0	0	0	0	0	0
International Aviation Bunkers**	0	0	-334	0	0	0	0	0	0	0	-334
Stock Changes	-34	-92	-28	-65	0	0	0	-5	0	0	-224
TPES	**19656**	**8436**	**1047**	**7118**	**6943**	**174**	**27**	**2197**	**-986**	**21**	**44632**

Source: IEA, 2011f

116,83 Mt. Czech Republic's primary energy source is coal and peat; as Table 2-6 indicates, coal and peat represents a significant amount of energy production with nearly 23 Mtoe of all 33 Mtoe which corresponds to nearly 60 percent of overall electricity production. Nuclear energy also constitutes nearly 21% of the overall Czech energy production in 2008 and is expected to be 33% in 2009. Between 1985 and 1987 there were four nuclear power reactors at which by end of 2008, each individually had a net capacity of 427 MWe. (WEC, 2010)

Other sources that comprise Czech Republic's energy diversification are domestic hydropower, oil and natural gas with an amount around 3% each. Due to the fact that the Czech Republic does not have adequate amount of oil and natural gas she is dependent on their imports thus energy imports constitute nearly half of the TPES.

2.1.1.6. Slovak Republic

Slovak Republic is a Central European country situated south of Poland. As of 2009 Slovak Republic has a population of 5,41 million and a GDP of $87,64 billion (current US$). Total energy production in 2008 is 6,42 Mtoe, electricity consumption 28,48 TWh and the corresponding CO_2 emission is 36,23 Mt. Slovak Republics energy demand is compensated primarily from outsources such that domestic production

Table 2-7 Energy Balance for Slovak Republic (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	624	232	0	87	4401	347	9	720	0	0	6420
Imports	3614	5985	1332	5129	0	0	0	53	809	0	16921
Exports	-170	-136	-3647	-154	0	0	0	-78	-765	0	-4950
International Marine Bunkers**	0	0	0	0	0	0	0	0	0	0	0
International Aviation Bunkers**	0	0	-63	0	0	0	0	0	0	0	-63
Stock Changes	-59	-29	-30	103	0	0	0	-10	0	0	-25
TPES	**4009**	**6052**	**-2408**	**5165**	**4401**	**347**	**9**	**684**	**45**	**0**	**18304**

Source: IEA, 2011g

constitutes only around 25% of TPES while imports constitute 65%. Nuclear power stands to be the primary domestic energy source with a share of 70% of overall domestic production.

Although Slovakian geothermal resources cover 27% of the country, obtaining thermal waters ranging from low temperatures to high temperatures, today the utilization of these resources are only for thermal baths, direct heating and fish farming. "Several projects are under development: a greenhouse heating scheme in Podhajska; a district heating scheme in Galanta and a space heating project in Slovakia's second city, Košice" (WEC, 2010: 494)

Between 1987 and 1985 four nuclear power plants were commissioned with a capacity of 408 MWe and another two 388MWe capacity power plant came into operation in 1998 and in 2000. Nevertheless in accordance with the EU accession in 2004, two of the nuclear power plants were decommissioned in 2006 hence "the remaining four reactors are reported to have a current net capacity of 1 711 MWe and to have provided 53.5% of the republic's electricity output in 2009" (WEC, 2010: 279).

2.1.1.7. Slovenia

Slovenia is a Central European country bordering the Adriatic Sea situated between Austria and Croatia. As of 2009 Slovenia has a population of 2,04 million and a GDP of $48,47 billion (current US$). Total energy production in 2008 is 3,67 Mtoe, electricity consumption 13,99 TWh and the corresponding CO_2 emission is 16,73 Mt.

Table 2-8 Energy Balance for Slovenia (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	1185	0	0	3	1635	346	0	504	0	0	3672
Imports	442	0	3664	876	0	0	0	18	535	0	5534
Exports	-1	0	-557	0	0	0	0	0	-673	0	-1230
International Marine Bunkers**	0	0	-64	0	0	0	0	0	0	0	-64
International Aviation Bunkers**	0	0	-35	0	0	0	0	0	0	0	-35
Stock Changes	-91	0	-52	0	0	0	0	0	0	0	-142
TPES	**1536**	**0**	**2957**	**878**	**1635**	**346**	**0**	**522**	**-138**	**0**	**7735**

Source: IEA, 2011h

Slovenia's primary energy supply source is oil and as Table 2-8 indicates all of the oil is imported along with natural gas which makes Slovenia an energy import dependent country such that nearly 70% of TPES originates from imported energy. In terms of domestic production coal, peat, hydropower and nuclear power holds a significant share and these are currently the only domestic energy sources utilized for heating and electricity generating purposes.

Since 1981 a nuclear power plant of 666MWe capacity has been operating at the border of Slovenia. The total output of this nuclear plant is hared half to half with Croatia is generating nearly 35% of Slovenian net electricity generation. Furthermore, another nuclear power plant is planned to be established in 2013 which expected to operate in 2017 with a net capacity of 1000MWe.

2.1.1.8. Hungary

Hungary is a Central European country situated northwest of Romania. As of 2009 Hungary has a population of 10,02 million and a GDP of $128,96 billion (current US$). Total energy production in 2008 is 10,50 Mtoe, electricity consumption 40,04 TWh and the corresponding CO_2 emission is 53,01 Mt. As Table 2-9 indicates, domestic

Table 2-9 Energy Balance for Hungary (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	1694	1245	0	2005	3875	18	117	1542	0	0	10496
Imports	1703	6877	2388	9323	0	0	0	66	1099	0	21456
Exports	-288	-493	-2818	-19	0	0	0	-88	-763	0	-4468
International Marine Bunkers**	0	0	0	0	0	0	0	0	0	0	0
International Aviation Bunkers**	0	0	-276	0	0	0	0	0	0	0	-276
Stock Changes	-72	-6	75	-752	0	0	0	4	0	0	-750
TPES	**3037**	**7624**	**-631**	**10558**	**3875**	**18**	**117**	**1524**	**336**	**0**	**26458**

Source: IEA, 2011i

energy production from oil, gas, nuclear and coal corresponds to nearly 30% of Hungary's TPES while the remaining energy need is fulfilled via energy imports of coal oil and natural gas. Although Hungary is believed to possess significant amount of geothermal resources namely she has the largest underground thermal water reserve in Europe, the amount of utilization of these reserves are yet to reach the adequate level of electricity production. Nevertheless geothermal resources are mostly canalized for heating purposes instead of electricity production.

In 2008 around 35% and in 2009 43% of the total domestic energy production originates from nuclear power. Between 1983 and 1987 four nuclear power plants with a net capacity of 1859 MWe were commissioned at Paks in central Hungary. In 2007 two of the power plants and in 2009 the other two were each upgraded to a capacity of 500 MWe which is nearly 8% higher than their initial capacity. (WEC, 2010)

2.1.1.9. Bulgaria

Bulgaria is a Southeaster European country bordering the Black Sea situated between Romania and Turkey. As of 2009 Bulgaria has a population of 7,58 million and a GDP of $48,72 billion (current US$). Total energy production in 2008 is 10,24 Mtoe, electricity consumption 35,02 TWh and the corresponding CO_2 emission is 48,78 Mt.

Table 2-10 Energy Balance for Bulgaria (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	4859	23	0	156	4130	243	43	789	0	0	10244
Imports	3232	7418	1362	2804	0	0	0	0	266	0	15081
Exports	-17	0	-3805	0	0	0	0	-30	-726	0	-4578
International Marine Bunkers**	0	0	-123	0	0	0	0	0	0	0	-123
International Aviation Bunkers**	0	0	-212	0	0	0	0	0	0	0	-212
Stock Changes	-581	-97	91	-47	0	0	0	0	0	0	-634
TPES	**7493**	**7344**	**-2686**	**2913**	**4130**	**243**	**43**	**759**	**-460**	**0**	**19779**

Source: IEA, 2011j

Bulgaria's primary domestic energy resource as presented in Table 2-10, is coal constituting 45%, followed by nuclear power sharing 40% of the total domestic energy production. On the other hand Bulgaria is a net importer of all the fossil fuels coal, crude oil, and natural gas except for nuclear and other renewable energy sources. Energy imports constitute a 75% of the TPES which clearly points out the fact that Bulgaria is dependent on energy imports.

Between 1974 and 1989 a total of six nuclear power plants were commissioned four of which has a capacity of 408 MWe each while two has a capacity of 953 MWe each. Aligned with the requirements for the EU membership two of these power plants were decommissioned in 2002 and two other in 2006. The remaining nuclear power plants as aforementioned constitute around 40% of the domestic electricity production which have increased in 2009 and by the end of 2020 the nuclear power capacity is expected to be 4 000 MWe.

2.1.1.10. Romania

Romania is a Southeaster European country bordering the Black Sea situated between Bulgaria and Ukraine. As of 2009 Romania has a population of 21,48 million and a GDP of $161,11 billion (current US$). Total energy production in 2008 is 28,78 Mtoe, electricity consumption 53,52 TWh and the corresponding CO_2 emission is 89,93

Table 2-11 Energy Balance for Romania (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	6728	4646	0	8990	2926	1479	26	3988	0	0	28782
Imports	2396	8331	1696	3530	0	0	0	111	79	0	16143
Exports	-19	-2	-5026	0	0	0	0	-4	-445	0	-5496
International Marine Bunkers**	0	0	-69	0	0	0	0	0	0	0	-69
International Aviation Bunkers**	0	0	-122	0	0	0	0	0	0	0	-122
Stock Changes	59	-38	235	-71	0	0	0	-42	0	0	142
TPES	**9164**	**12936**	**-3286**	**12449**	**2926**	**1479**	**26**	**4053**	**-365**	**0**	**39380**

Source: IEA, 2011k

Mt. As of 2008 Romania's domestic energy production constitutes around 73% of the TPES. As Table 2-11 indicates Romania has significant amount of coal, oil and natural gas reserves along with considerable amount of hydropower, nuclear and other renewable. Nevertheless in order to compensate the overall consumption Romania still imports oil and natural gas yet in order to decrease this dependency improvement in nuclear power is considered.

Currently Romania obtains two nuclear power plants one of which was commissioned in 1996 with a capacity of 655 MWe and the other in 2007. The two reactors overall contribution to Romania's electricity generation is nearly 20%. In February 2010 Romanian Power Company EnergoNuclear and Canadian AECL had signed a contract to assess the technical and commercial viability, and planning of another two nuclear power plants.

With a capacity of 14 000 MW, Romania has the highest wind power in Southeastern Europe. "In Romania there are five distinct wind zones, depending on the existing potential of wind energy, climate and terrain. By end-2008, 16 units with a total capacity of 9.5 MW had been installed, generating 11.02 GWh/yr" (WEC, 2010: 534).

2.1.2. EU Candidate Countries

2.1.2.1. Turkey

Turkey is a Southeast European, Northwest Middle Eastern and Southwest Asian thus in this sense a Eurasian and Middle Eastern country. Turkey is peninsula bordering the Black Sea in the North, Mediterranean Sea in the South, Aegean and the Marmara

Table 2-12 Energy Balance for Turkey (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	16675	2134	0	837	0	2861	1643	4828	0	0	28979
Imports	12856	21570	14406	30603	0	0	0	0	68	0	79503
Exports	0	0	-6527	-359	0	0	0	0	-96	0	-6982
International Marine Bunkers**	0	0	-653	0	0	0	0	0	0	0	-653
International Aviation Bunkers**	0	0	-1302	0	0	0	0	0	0	0	-1302
Stock Changes	-70	-141	66	-898	0	0	0	0	0	0	-1043
TPES	**29461**	**23564**	**5990**	**30184**	**0**	**2861**	**1643**	**4828**	**-29**	**0**	**98502**

Source: IEA, 2011l

Sea in the West. As of 2009 Turkey has a population of 74,81 million and a GDP of $614,60 billion (current US$). Total energy production is 28,98 Mtoe, electricity consumption 170,60 TWh and the corresponding CO_2 emission is 263,53 Mt. As Table

2-12 indicates primary domestic energy source of Turkey is coal and peat constituting nearly half of the total domestic production. Nevertheless Turkey imports oil, natural gas and coal which overall constitute nearly 80% of the TPES thus it can be inferred as Turkey dependent on energy imports.

Although currently there is no electricity generated from nuclear power, in 2008 a program was undertaken to commission a nuclear power plant on the Mediterranean coast. In 2010 an agreement between Turkey and Russian Federation company Rosatom to construct four nuclear power plants with a capacity of 1 200 MWe each at the corresponding coast. (WEC, 2010)

Turkey receives significant amount of solar radiation which is utilized mostly in the form of solar thermal collectors used to heating water and cooling spaces. With the increasing tourism activities in Turkey the need for hot water and the scarce energy resources led the solar market to grow intensively such that it "is estimated that over 10 million m^2 of flat plate collectors have been installed (one of the highest levels for any country in the world)" (WEC, 2010: 449). Considering the high amount of solar radiation and the need for energy diversification, the utilization of solar energy will continue to grow. Turkish Parliament's legislation came into force in 2005 to increase the use of renewable energy as a result, the installed wind capacity which was 18MW by the end of 2004 have risen to 458 MW. Electricity generation from wind turbines have also increased nearly 78% by the end of 2009 and is expected to reach 1 030MW in 2010. By 2020 the government is planning to increase of share of wind and solar energy in electricity generating to 10%.

Explorations stared and still continuing since 1960s have indicated that Turkey obtains significant amount of geothermal power potential owing to the fact that Turkey geologically is part of the great Alpine belt which was formed during the Tertiary Period (65 million to 1.6 million B.C.). About 7% of the geothermal potential have been harnessed and utilized in space heating, by the end of 2009 it was estimated that the direct use installed capacity was 2 084 MWt (Megawatt Thermal) and the electricity generating capacity was 47,4 MWe moreover the expected capacity by the end of 2010 is 100MWe. (WEC, 2010)

2.1.2.2. Macedonia

The Former Yugoslav Republic of Macedonia is a Southeaster European country situated north of Greece. As of 2009 Macedonia has a population of 2,04 million and a GDP of $9,22 billion (current US$). Total energy production in 2008 is 1,72 Mtoe, electricity consumption 7,60 TWh and the corresponding CO_2 emission is 8,96 Mt. As it

Table 2-13 Energy Balance for Macedonia (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	1470	0	0	0	0	72	9	165	0	0	1717
Imports	153	1078	219	97	0	0	0	0	235	0	1783
Exports	-1	0	-377	0	0	0	0	-1	0	0	-378
International Marine Bunkers**	0	0	0	0	0	0	0	0	0	0	0
International Aviation Bunkers**	0	0	-6	0	0	0	0	0	0	0	-6
Stock Changes	-45	6	19	0	0	0	0	8	0	0	-11
TPES	**1578**	**1084**	**-145**	**97**	**0**	**72**	**9**	**173**	**235**	**0**	**3103**

Source: IEA, 2011m

is presented in Table 2-13 Macedonia's primary domestic energy source, sharing 85% of the total domestic production is coal and peat. There are no oil and natural gas reserves thus Macedonia imports all of the required oil and natural gas. In this regard energy imports constitute nearly half of the TPES. Furthermore in Table 2-13 it is observable that Macedonia uses hydropower, biomass, solar energy and geothermal as sources of renewable energy and mostly utilized as electricity generation and space heating purposes. Macedonia has slower developing energy profile compared to other Southeast European countries and as an EU candidate requires robust energy strategies and policies.

2.1.2.3. Croatia

Croatia is a Southeaster European country situated north of Greece. As of 2009 Croatia has a population of 4,43 million and a GDP of $63,03 billion (current US$). Total energy production in 2008 is 3,95 Mtoe, electricity consumption 17,20 TWh and the corresponding CO_2 emission is 20,93 Mt. As Table 2-14 indicates, Croatia is an energy import dependent country such that nearly 80% of the TPES is imported. Primary domestic energy source is with a share of 55% is natural gas and primary imported resource is oil. As well as Macedonia, Croatia has one of the slowly developing energy

Table 2-14 Energy Balance for Croatia (ktoe)

SUPPLY and CONSUMPTION	Coal and Peat	Crude Oil	Oil Products	Gas	Nuclear	Hydro	Geothermal, Solar, etc.	Combustible Renewables and Waste	Electricity	Heat	Total*
Production	0	889	0	2194	0	449	11	405	0	0	3946
Imports	796	3758	1816	986	0	0	0	3	702	0	8061
Exports	0	0	-1772	-559	0	0	0	-81	-136	0	-2549
International Marine Bunkers**	0	0	-21	0	0	0	0	0	0	0	-21
International Aviation Bunkers**	0	0	-51	0	0	0	0	0	0	0	-51
Stock Changes	-87	84	-263	-44	0	0	0	0	0	0	-311
TPES	**709**	**4731**	**-292**	**2576**	**0**	**449**	**11**	**326**	**566**	**0**	**9075**

Source: IEA, 2011n

markets in the southeast Europe and as an EU candidate requires robust strategies and policies in order to develop align her energy market with European markets.

In terms of renewable energy resource although geothermal and solar power constitutes relatively low amount in the domestic energy diversification yet “Croatia has very high spatial variability of solar irradiation, especially in the near-coast areas bounded by the high mountains. Solar thermal collectors can generate around 600 kWh/m2 for the continental part of Croatia and around 1 000 kWh/m2 for the coastal area” (WEC, 2010: 429).

PART THREE

ENERGY CONSUMPTION, CARBON GAS EMISSIONS AND ECONOMIC GROWTH

3. Literature Review

The connection and relationship between energy and economic growth have been a topic of great significance between economists thus there are numerous studies concerning the causality relationship of energy and growth. “The relationship between energy consumption and economic growth has been widely discussed since Kraft and Kraft (1978) found evidence of a unidirectional causal relationship running from Gross National Product (GNP) to energy consumption in the US using data over the 1947–1974 period” (Chen, Kuo and Chen, 2007: 2611). The reason underlying this fact is the increasing demand for energy, rising debates over greenhouse gas emissions, the international awareness over global warming and the researches indicating that proven fossil fuel reserves are in fact depletable thus unreliable for long term economic growth. Although the topic arises interest and a range of studies are conducted in this context, a consensus indicating the true relationship between economic growth and energy consumption is yet to be reached.

Furthermore, the studies that have analyzed the relationship also indicate conflicting results such that on one hand there are studies asserting there is no causality and on the other hand some of the studies stand to prove the opposite. The conflicting results are mainly due to the fact that each study inquires a different country, for a different time range and with a different econometric analysis. The estimation results are very sensitive even for studies conducted for the same country might reveal conflicting results because of the corresponding reasons.

Although it is important to propound that there is a causal relationship between energy consumption and economic growth, it is the direction that mostly matter especially for the policy makers. “The direction of causality is highly relevant for policy makers. For instance, if causality runs from energy consumption to economic growth, energy conservation policies that have the aim of reducing energy consumption may have a negative impact on an economy's growth" (Belke, Dobnik and Dreger, 2010: 2).

In this regard the literature proposes four different hypotheses in order to clarify the causality and the direction it runs through. The categories listed in the studies Apergis and Payne (2009a,b,c) and Ozturk (2010) are as such; no causality between energy consumption and economic growth, unidirectional causality from energy consumption to economic growth, unidirectional causality from economic growth to energy consumption and bidirectional causality between economic growth and energy consumption. As can be inferred no causality or known as "neutrality hypothesis" indicates that there is no correlation between economic growth and energy consumption thus policies regarding the energy consumption will not have any effect on economic growth. The second, unidirectional causality from economic growth to energy consumption, also referred to as "conservation hypothesis" propounds that there is a correlation between economic growth and energy consumption thus an increase in economic growth will simultaneously increase energy consumption or vice versa.

The third, unidirectional causality from energy consumption to economic growth, known as "growth hypothesis" indicates that there is a correlation between energy consumption and economic growth such that a decrease in energy consumption will lead to a decrease in economic growth thus in that case the country is energy dependent. The last, bidirectional causality which means there is correlation between economic growth and economic growth which runs both ways such that any alteration in either one will cause proportionate change in the other, also referred to as "feedback hypothesis".

The following sections of this part will constitute of the studies conducted regarding the causality between energy consumption and economic growth in the light of the aforementioned four categories. All the studies since Kraft and Kraft (1978) will be observed in this process and the results, the methodology used, time range and corresponding country or countries will be presented.

3.1. Studies on Energy Consumption and Economic Growth Nexus

3.1.1. Country Specific Studies

Kraft and Kraft (1978) have been the pioneering work in the area of energy consumption and economic growth has been conducted for USA between the years 1947-1974 using Granger Causality tests. The empirical results of the study indicated that there is a unidirectional causality running from economic growth to energy consumption which is consistent with the conservation hypothesis.

Akarca and Long (1980) have studied the relationship between energy consumption and economic growth in USA for the time period of 1950-1970 using the SIM's technique in order to investigate the prior study results of Kraft and Kraft (1978). Akarca and Long (1980) criticized that Kraft and Kraft's (1978) work was not presenting a statistical forecast rather a single equation regression reflecting a behavioral relationship and was spurious. Akarca and Long (1980) assert that Kraft and Kraft (1978), although available, did not use the data for 1900-1946 which includes the two world wars that might have altered the structural relation yet they have included 1970-74 which are the years of recession and oil embargo. (Akarca and Long, 1980: 327) Finally, contrary to Kraft and Kraft (1978), Akarca and Long's (1980) study did not point out a causal relationship.

Yu and Hwang (1984) have reanalyzed in their study the causality between GNP and energy consumption in the USA for the time range 1947-1979 with updated data different from the previous studies and have used the Sim's technique and Granger Causality tests. Yu and Hwang (1984) found outcomes consistent with that of Akarca and Long (1980) when the study sample is eliminated from the two years of embargo, 1973-1974, indicating that there may have been structural changes during the two years. Finally, although "empirical results clearly indicate a strong statistical relationship between GNP and energy consumption, the causality tests reveal no unidirectional causal linkage between GNP and energy" (Yu and Hwang, 1984: 188).

Abosedra and Baghestani (1989) have reexamined the causal relationship between GNP and energy consumption for the years 1947-1972, 1947-1974, 1947-1979 and 1947-1987 in USA using the Granger causality tests. The empirical results of the study "based on the direct Granger test, it is concluded that, for all the sample periods, there is a unidirectional causation from GNP to energy consumption at the fourth year lag, indicating that our test results are not sensitive to the sample period" (Abosedra and Baghestani, 1989)

Hwang and Gum (1991) have studied Taiwan for the year 1961-1990 using cointegration test and error correction model to investigate the relationship between energy consumption and economic growth. The results indicate bidirectional causality supporting the feedback hypothesis.

Yu and Jin (1992) have analyzed the relationship between energy consumption and economic growth or employment for USA between the years 1974-1990 using Cointegration and Granger causality. As a conclusion to their study Yu and Jin (1992) "have found that the long-run equilibrium relationship fails to exist between energy consumption and the level of real output or employment" (Yu and Jin, 1992: 265).

Stern (1993) examined the causal relationship between GDP and energy uses in the USA for the period 1947-1990 using a multivariate vector auto-regression (VAR) model. Stern asserts that the previous tests used in the literature (Granger Causality) does not allow a direct test of relative explanatory variables thus a VAR of GDP, energy use, capital stock and employment is estimated. Stern (1993)'s conclusion points out that "Although there is no evidence that gross energy use Granger causes GDP, a measure of final energy use adjusted for changing fuel composition does Granger cause GDP" (Stern, 1993: 137). Furthermore, Stern (1998) has extended the analysis of Stern (1993) which investigated the causal relationship between energy consumption and economic growth to 1948-1994. The result of the analysis does not contradict with the previous Stern (1993) and indicates causality running from energy consumption to economic growth.

Cheng (1995) have examined the nexus between energy consumption and economic growth with a different approach with both bivariate and multivariate models by applying methods of cointegration and Hsiao`s version of the Granger causality. As a result of the study Cheng (1995) asserts that there is no causal relationship between energy consumption and economic growth. Cheng (1995) also refers to the fact that the results may vary from country to country and propounds that USA has a service oriented economy in which any alteration to the energy consumption logically will not affect the GDP.

Cheng and Lai (1997) applied Hsiao's version of Granger causality to investigate the relationship between GNP and energy consumption within the years 1954-1993 for Taiwan. The results of the study reveal that causality runs from economic growth to energy consumption but not vice versa. The results contradict with that of Hwang and Gum (1991) which stated that there is bidirectional causality between energy consumption and economic growth.

Cheng (1998) studied Japan using Hsiao's Granger causality for the years 1952-1995, while Cheng (1999) studied India using cointegration, error correction modeling and Granger causality for the years 1952-1999. The empirical results of both studies reveal that there is unidirectional causality running from economic growth to energy consumption.

Soytas, Sari and Ozdemir (2001) have used Johansen-Juselius Cointegration Methodology and Vector Error Correction Modeling to analyze the causal relationship between energy consumption and economic growth for Turkey within the years 1960-1995. The results of the study propounds that there is unidirectional relationship running from energy consumption to economic growth.

Aqeel and Butt (2001) have investigated the direction of the causal relationship between energy consumption and economic growth in Pakistan for the years 1955-1996 using cointegration and Hsiao's version of Granger causality tests. "The estimated results infer that economic growth causes total energy consumption" (Aqeel and Butt, 2001: 109).

Glasure (2002) have revisited the causal relationship between energy consumption and economic growth for Korea within the years 1961-1990 using the cointegration, vector error correction model. The findings of this study contradict with Glasure and Aie-Rie (1997) which stated that there is no causal relationship between energy consumption and economic growth. Nevertheless Glasure (2002) asserts that the absence of a causal relationship is due to the omitted variables "hence, the empirical examination of the association between energy and real income must include money, government spending, the oil price and also must control for the two oil price shocks" (Glasure, 2002: 357).

Hondroyiannis, Lolos and Papapetrou (2002) investigated the relationship between energy consumption and economic growth for Greece within the years 1960-1996 using vector error correction model. The results of the study support the idea feedback hypothesis such that in Greece energy and consumption and economics growth has a bidirectional causal relationship.

Altinay and Karagol (2004) investigated the causality between energy consumption and economic growth in Turkey for the years 1950-2000 using Hsiao's version of Granger causality method. The study asserts that the data is stationary thus taking the first difference of the data is not required and if taken it would result in a spurious causality between the series. The empirical results of the study indicate that there is no evidence supporting the causality between energy consumption and GDP. The results of the study contradict with Soytas et.al. (2001) and Soytas and Sari (2003) which proposed that causality runs from energy consumption to economic growth.

Ghali and El-Sakka (2004) analyzed the direction of the causality between energy use and economic growth in Canada within the years 1961-1997 using Johansen cointegration, vector error correction models and Granger causality. "Based on the neo-classical one sector aggregate production technology, we developed a VEC model after testing for multivariate cointegration between output, capital, labor and energy use" (Ghali and El-Sakka, 2004: 237). The results of the study reveal that for Canada the causality exists in both directions supporting the feedback hypothesis.

Paul and Bhattacharya (2004) have studied the direction of the causal relationship between energy consumption and economic growth in India using Engle Granger cointegration along with standard Granger causality for 1950-1996 data. The results indicate bidirectional causality between the series. This study does not support Cheng (1999) which asserted that causality runs from economic growth to energy consumption.

Oh and Lee (2004) studied the causality between energy consumption and economic growth applying vector error correction model instead of a vector autoregressive model within the years 1970-1999 for Korea. "Empirical results for Korea over the period 1970–1999 suggest a long run bidirectional causal relationship between energy and GDP, and short run unidirectional causality running from energy to GDP" (Oh and Lee, 2004: 51). Nevertheless while previous studies such as Glasure (2002) stating bidirectional causality, Yu and Choi (1985), Soytas and Sari (2003) stating unidirectional causality from GDP to energy use contradict with Oh and Lee (2004); others such as Masih and Masih (1997) have reached a similar conclusion.

Wolde-Rufael (2004) investigated the causal relationship between different kinds of industrial energy and economic growth in Shangai for the years 1952-1999 using Toda and Yamamoto's Granger causality tests. The findings of the study indicate that although there is no causality running from oil consumption to economic growth, there is causality running from coal, electricity and total energy consumption to economic growth.

Lee and Chang (2005) studied the causality between energy consumption and economic growth for Taiwan during 1954-2003 using the aggregate and disaggregate data of energy consumption and Johansen–Juselius cointegration and vector error correction models. The empirical results show that causality exists in different directions between specific types of energy sources and GDP moreover; the overall findings assert that energy consumption causes economic growth supporting the growth theory.

Ang (2007) examined the dynamic causal relationship between CO_2 emissions, energy consumption and output growth for France within the years 1960-2000 using cointegration and multivariate vector error correction modeling techniques. The empirical results propound that increasing use of energy lead to an increase in CO_2 emissions moreover; pollutant emissions in the long run are correlated with economic growth. The results of the causality tests indicate that in the long run economic growth causes CO_2 emissions and energy consumption while, in the short run the growth hypothesis holds.

Lee and Chang (2007a) analyzed the linear and nonlinear effect of energy consumption on economic growth in Taiwan for the period 1955-2003 using Granger causality, cointegration and vector error correction model. “The results for the linear model framework appear mixed, depending on the theoretical setting used to estimate the effect of energy consumption on growth. In the nonlinear case, we find evidence of a level-dependent effect between two variables.” (Lee and Chang, 2007a: 2293). Furthermore, the overall results support the growth hypothesis for Taiwan.

Jobert and Karanfil (2007) provided analysis of the causal relationship between energy consumption and economic growth for Turkey within the years 1960-2003 using Granger causality. The study is conducted in two sections of which one deals with the aggregate level of consumption and production while the other deals on specifically on the industrial level. Although previous studies such as Murray and Nan (1996), Soytas et.al. (2001) and Soytas and Sari (2003) propound that there is causal relationship for Turkey, empirical results of Jobert and Karanfil (2007) along with Altinay and Karagol (2004) support the neutrality hypothesis.

Ho and Siu (2007) investigated the electricity policy debates in Hong Kong and the causal relationship between electricity usage and economic growth using cointegration and vector error correction models within the years 1966-2002. The study is concluded with the “following findings: (1) there is a long run equilibrium relationship between real GDP and electricity consumption; (2) a one-way causal effect exists from electricity consumption to real GDP” (Ho and Siu, 2007: 2507).

Zamani (2007) investigated the causal relationship between overall GDP and energy consumption of different kinds of energy sources for Iran within 1967-2003 period using vector error correction. The empirical results of the study indicate that for natural gas and petroleum the causality runs both ways nevertheless for the overall energy consumption there is unidirectional causality running from economic growth to overall energy consumption.

Lise and Van Montfort (2007) studied the causal relationship between energy consumption and GDP using cointegration analysis for Turkey within the period 1970-2003 considering the fact that the energy use for Turkey is expected to grow significantly annually until 2025. The cointegration results strongly show that energy consumption and GDP are co-integrated. The overall results indicate that there is a unidirectional causality running from GDP to energy consumption supporting the conservation hypothesis. Furthermore the study also concludes that energy consumption and economic growth are correlated such that with increasing growth, energy consumption also increases.

Karanfil (2008) analyzed the long run causal relationship between energy consumption and real GDP growth considering the unrecorded economy in Turkey for the period 1970-2005 using Granger causality and cointegration tests. The study dwells on the fact that due to the unrecorded economy GDP is not measured correctly. The empirical results of the study when error correction techniques are used reveal that both in the short and long run the causality runs from GDP growth to energy consumption. Nevertheless when the unrecorded economy is inserted into the regression, the results show neither cointegration nor causality between energy consumption and economic growth.

Ang (2008) studied the long run relationship between output, pollutant emissions and energy consumption in Malaysia for the period 1971-1999 using cointegration analysis using Johansen cointegration tests and vector error correction techniques. The results for the energy consumption and pollution emissions show similarities with that of Ang (2007) in supporting the idea that pollution and energy use are positively related to economic growth in the long run. The overall results assert that both in the short and long run the causality runs from economic growth to energy consumption.

Erdal, Erdal and Esengun (2008) reexamined the causal relationship between energy consumption and real GNP for Turkey within the years 1970-2006 using unit root tests, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP), Johansen cointegration tests and pair-wise Granger causality. The empirical results support the idea that energy consumption and economic growth are co-integrated unlike Altinay and Karagol (2004), Jobert and Karanfil (2007) and Karanfil (2008) (unrecorded economy taken into account). Furthermore different from the previous studies, Lise and Van Montfort (2007), Karanfil (2008) (absent of unrecorded economy), Murray and Nan (1996), Soytas et.al. (2001) and Soytas and Sari (2003) in terms of the direction such that Erdal et.al. (2008) propounds that the causality is bidirectional.

Bowden and Payne (2009) used sectoral and primary U.S. energy data between the years 1949-2006 using Toda and Yamamoto's version of Granger causality to examine the causal relationship between energy consumption and economic growth. The findings of the study ascertain that the causal relationship is not similar across sectors such that there is no causality between transportation and total primary energy consumption and bidirectional causality is observed between commercial and residential primary energy consumption. Overall results indicate that there is unidirectional causality running from total energy consumption to real GDP.

Halicioglu (2009) examined the dynamic causal relationship between energy consumption, carbon emissions, income and foreign trade for Turkey between the years 1960-2005 using the bounds testing for cointegration, autoregressive distributed lag (ARDL) and Granger causality. The empirical results suggest that both in the short and long run there are only two Granger causalities observed one of which the Granger causality runs from CO_2 emissions to income and vice versa supporting the feedback hypothesis and the other bidirectional causality between energy consumption and CO_2 emissions. Hence there is no evidence supporting any causality between energy consumption and GDP growth.

Payne (2009) used renewable and non renewable energy consumption and real GDP data of 1949-2006 for USA in order to analyze the causal relationship between the series using Toda and Yamamoto's version of Granger causality. "The results indicate the absence of Granger-causality between renewable and non-renewable energy consumption and real GDP lending tentative support for the neutrality hypothesis." (Payne, 2009: 577)

Soytas and Sari (2009) investigated the long run causal relationship between economic growth, carbon emissions and energy consumption in Turkey for the years 1960-2000 using the Toda and Yamamoto's version of the Granger causality. Soytas and Sari (2009) analyzes the relationship in the context of Turkey's EU candidacy and its implications on the energy policies. The empirical results of the study revealed that there is Granger causality relationship between energy consumption and economic growth which is a similar conclusion as the previous studies Altinay and Karagol (2004), Jobert and Karanfil (2007), Karanfil (2008), Halicioglu (2009).

Belloumi (2009) implemented the Johansen cointegration technique, vector error correction model to the 1971-2004 energy use per capita and per capita GDP data for Tunisia in order to detect the direction of the causality between energy consumption and economic growth. The results ascertains the cointegration between the series however, the direction of the causality varies in the short and long run such that in the long run bidirectional causality is observed; nevertheless in the short run the evidence supports unidirectional causality running from energy consumption to economic growth.

Zhang and Cheng (2009) applied a multivariate model of economic growth, energy use, carbon emissions, capital and urban population and Granger causality to 1960-2007 data for China in order to investigate the existence and direction of the causality relationship between economic growth, energy consumption and carbon gas emission. Although the evidence suggest that there is no causality running from carbon emissions and energy consumption to economic growth the vice versa is valid supporting the conservation hypothesis. And along with the previous studies Zhang and Cheng (2009) have also found results supporting the causal relationship between energy consumption and carbon gas emissions.

Tsani (2010) examined the causal relationship between aggregate and disaggregate levels of energy consumption and economic growth in Greece for the period 1960-2006 using Toda and Yamamoto's version of Granger causality. The results of the study at the aggregate levels support a unidirectional causality running from total energy consumption to economic growth and at the disaggregate levels there is evidence for bidirectional causality between industrial and residential energy use and GDP.

Chang (2010) applied vector error correction and the multivariate cointegration Granger causality tests to analyze the direction of the causality between carbon emissions, energy consumption and economic growth in China between the years 1981-2006. The study concludes two bidirectional causal relationships one of which from GDP to CO_2 emissions and energy consumption while the second from electricity consumption to economic growth.

Bartleet and Gounder (2010) examined the causal relationship between energy consumption and economic growth using trivariate demand side, multivariate production side models followed by the ARDL and Granger causality for both long and short run in New Zealand within the years 1960-2004. The empirical results of the trivariate model indicate that there is unidirectional causality running from GDP to total energy consumption supporting the conservation hypothesis.

Arbex and Perobelli (2010) used a growth model that includes renewable and nonrenewable resources into the production function and assumes perfect mobility of goods and services in order to analyze the impacts of economic growth on energy consumption in Brazil within the period 1990-2003. Arbex and Perobelli (2010)'s "approach integrates an exogenous growth (Solow) model and an input–output (Leontief) model to analyze energy use and economic growth at an economic sectoral level." (Arbex and Perobelli, 2010: 44). The study indicates that on the sectoral basis there is correlation between the series however for some sectors although the growth rates are high the corresponding energy use is low.

Ozturk and Acaravci (2010a) used ARDL bounds testing approach of cointegration in order to reexamine the causal and long run relationship between carbon emissions, energy consumption, economic growth and employment ratio in Turkey for the period 1968-2005. The empirical results indicate that there is no causality running between the series nevertheless at 5% confidence level the analysis reveals that there is long run relationship between carbon emission, energy consumption and economic growth. Furthermore the study also points out the fact that the EKC hypothesis does not hold for Turkey within the corresponding years and series.

Menyah and Wolde-Rufael (2010) analyzed the causal relationship between economic growth, carbon emissions and energy consumption in South Africa for the period 1965-2006 using bonds test for cointegration and Toda and Yamamoto's version of Granger causality. As well as previous studies Menyah and Wolde-Rufael (2010) also have found cointegration relationship between the series. The empirical results support that there is unidirectional causality running from carbon emissions to economic growth, from energy consumption to economic growth and from energy consumption to carbon gas emission absent of the feedback hypothesis.

Li, Dong, Li, Liang, and Yang (2011) implemented panel unit root, heterogeneous cointegration and panel based dynamic ordinary least squares (OLS) to reexamine the causality between energy consumption and economic growth for specific provinces of China within the period of 1985-2007. The study ascertains that energy is indeed an essential factor in production and finds evidence on the long run relationship between the series. Li et.al. (2011) have found that economic growth is caused by energy consumption which supports the growth hypothesis.

Zhang (2011) investigated the nexus between energy consumption and economic growth for Russia using the state space model and time-varying cointegration approach for the period 1970-2008. The first results of the study are that there is cointegration between Russia's energy consumption and economic growth. The overall conclusion is that there is bidirectional causal relationship between the series.

Yalta (2011) employed the maximum entropy bootstrap model to the energy consumption and real GDP in order to test the causal nexus for Turkey within the years 1950-2006. This model differs in a way from the previous models implemented that it does not require any data transformation such as differencing or detrending. "Our extensive testing reveals that a statistically significant relationship does not exist. In addition, we employ a multivariate framework that can help avoid a potential omitted variable bias and better explain the EC and GDP nexus in an open economy setting. Controlling for the real exchange rate and oil prices, the results once again indicate no causal relationship between EC and GDP in all considered cases." (Yalta, 2011: 7)

Table 3-1 Summary of the Country Specific Studies

Study	**Periods**	**Country**	**Methodology**	**Causal Relationship**
Kraft and Kraft (1978)	1947-1974	USA	Granger Causality	GDP --> EC
Akarca and Long (1980)	1950-1970	USA	SIM's Technique	GDP --- EC
Yu and Hwang (1984)	1947-1979	USA	SIM's Technique	GDP --- EC
Abosedra and Baghestani (1989)	1947-1987	USA	Granger Causality	GDP --> EC
Hwang and Gum (1991)	1961-1990	Taiwan	Cointegration, Error Correction	GDP <--> EC
Yu and Jin (1992)	1974-1990	USA	Cointegration, Granger Causality	GDP --- EC
Stern (1993)	1947-1990	USA	Multivariate VAR, Granger Causality	EC --> GDP
Cheng (1995)	1947-1990	USA	Cointegration, Granger Causality	GDP --- EC
Cheng and Lai (1997)	1954-1993	Taiwan	Hsiao's Granger causality	GDP --> EC
Cheng (1998)	1953-1995	India	Hsiao's Granger causality	GDP --> EC
Stern (1998)	1948-1994	USA	Multivariate VAR, Granger Causality	EC --> GDP
Cheng (1999)	1953-1999	India	Co-integration, Error Correction	GDP --> EC
Soytas et al. (2001)	1960-1995	Turkey	Johansen-Juselius Cointegration, VEC Modeling	GDP <--> EC
Aqeel and Butt (2001)	1955-1996	Pakistan	Hsiao's Granger causality	EC --> GDP
Glasure (2002)	1961-1990	Korea	Cointegration, Error Correction	GDP <--> EC
Hondroyiannis et al. (2002)	1960-1996	Greece	Vector Error Correction	GDP <--> EC
Altinay and Karagol (2004)	1950-2000	Turkey	Hsiao's Granger causality	GDP --- EC
Ghali and El-Sakka (2004)	1961-1997	Canada	Johansen cointegration, VEC and Granger causality	GDP <--> EC
Paul and Bhattacharya (2004)	1950-1996	India	Cointegration, Granger Causality	GDP <--> EC
Oh and Lee (2004)	1970-1999	Korea	VEC and Granger causality	EC --> GDP
Wolde-Rufael (2004)	1952-1999	Shangai	Toda and Yamamoto's Granger causality	EC --> GDP
Lee and Chang (2005)	1954-2003	Taiwan	Johansen-Juselius Cointegration, VEC Modeling	EC --> GDP
Ang (2007)	1960-2000	France	Cointegration, Error Correction, Granger Causality	EC --> GDP
Lee and Chang (2007a)	1955-2003	Taiwan	Cointegration, Error Correction, Granger Causality	EC --> GDP
Jobert and Karanfil (2007)	1960-2003	Turkey	Granger Causality	EC---GDP
Ho and Siu (2007)	1966-2002	Hong Kong	Cointegration, Error Correction	EC---GDP
Zamani (2007)	1967-2003	Iran	Cointegration, Error Correction, Granger Causality	GDP --> EC
Lise and Van Montfort (2007)	1970-2003	Turkey	Cointegration, Granger Causality	GDP --> EC
Karanfil (2008)	1970-2005	Turkey	Cointegration, Granger Causality	GDP --> EC
Ang (2008)	1971-1999	Malaysia	Johansen-Juselius Cointegration, VEC Modeling	EC --> GDP
Erdal et al. (2008)	1970-2006	Turkey	Johansen Cointegration, pair-wise Granger causality	GDP <--> EC
Bowden and Payne (2009)	1949-2006	USA	Toda and Yamamoto's Granger causality	EC --> GDP
Halicioglu (2009)	1960-2005	Turkey	Cointegration, ARDL, Granger Causality	EC---GDP
Payne (2009)	1949-2006	USA	Toda and Yamamoto's Granger causality	EC---GDP
Soytas and Sari (2009)	1960-2000	Turkey	Toda and Yamamoto's Granger causality	EC---GDP
Belloumi (2009)	1971-2004	Tunisia	VEC and Granger causality	EC---GDP
Zhang and Cheng (2009)	1960-2007	China	Granger Causality	GDP --> EC
Tsani (2010)	1960-2006	Greece	Toda and Yamamoto's Granger causality	EC --> GDP
Chang (2010)	1981-2006	China	Cointegration, Error Correction, Granger Causality	GDP <--> EC
Bartleet and Gounder (2010)	1960-2004	New Zealand	ARDL and Granger Causality	GDP --> EC
Ozturk and Acaravci (2010a)	1968-2005	Turkey	ARDL and Granger Causality	EC---GDP
Menyah and Wolde-Rufael (2010)	1965-2006	South Africa	Toda and Yamamoto's Granger causality	EC --> GDP
Li et al. (2011)	1985-2007	China	Panel OLS	EC --> GDP
Zhang (2011)	1970-2008	Russia	State Space Model, Time-varying Cointegration Approach	GDP <--> EC
Yalta (2011)	1950-2006	Turkey	Maximum Entropy Bootstrap Model	EC---GDP

3.1.2. Multi-Country Specific Studies

Yu and Choi (1985) have analyzed five countries namely, United Kingdom (UK), Philippines, USA, Poland and Korea using Granger Causality test between the years 1950-1976. As aforementioned, since the estimations are sensitive there have been three different conclusions. As for UK, USA and Poland the estimations have shown no causality supporting the neutrality hypothesis while for Philippines there have been a unidirectional causality from energy consumption towards economic growth supporting the growth hypothesis and for Korea the results indicate a unidirectional causality from economic growth towards energy consumption supporting the conservation hypothesis.

Erol and Yu (1987) have conducted a similar study using the Granger Causality tests for six industrialized countries; Japan, Italy, Germany, Canada, France and UK for the time range 1952-1982. The results of the study indicate bidirectional causality for Japan, unidirectional causality from economic growth to energy consumption for Italy and Germany, unidirectional causality from energy consumption to economic growth for Canada and no causality for France and UK. If recalled, the empirical results of Yu and Choi, (1985) for UK, also indicated no causality which is consistent with Erol and Yu (1987).

Nachane, Nadkarni, and Karnik (1988) have analyzed 16 countries of which 11 of them are less developed countries (LDC) and 5 are developed countries (DC), for the years 1950-1985 using Cointegration, Sim's and Granger Causality tests. The empirical results assert that except for Venezuela and Colombia, whom the neutrality hypothesis holds, there is bidirectional causality between energy consumption and economic growth.

Masih and Masih (1996), based on Johansen's multivariate cointegration tests and error correction models, have analyzed the cointegration between energy consumption and real income for six Asian countries; India, Pakistan, Indonesia, Malaysia, Singapore and Philippines. The results of the estimations indicate that neutrality hypothesis holds for Malaysia, Philippines, which is inconsistent with the previous study Yu and Choi (1985) where there was a causality from energy consumption to economic growth, and Singapore. Nevertheless, growth hypothesis holds for India, conservation hypothesis holds for Indonesia and feedback hypothesis holds for Pakistan.

Masih and Masih (1997) have studied for the years 1952-1992 using “the most recent Johansen's multiple cointegration tests preceded by various unit root or non-stationarity tests for Korea and Taiwan” (Masih and Masih, 1997: 417). Furthermore the direction of the causality is tested by a dynamic vector error correction model. The empirical results indicate that in both Korea and Taiwan a bidirectional causal relationship exists between energy consumption and economic growth.

Glasure and Aie-Rie (1997) examined the causality between energy consumption and GDP for South Korea and Singapore using cointegration and error correction modeling within the years 1961-1990. Although the results of the cointegration and error correction presents bidirectional relationship between GDP and energy consumption for both South Korea and Singapore, Granger causality estimations indicate that there is no causality for South Korea while unidirectional causality from energy consumption to GDP for Singapore.

Asafu-Adjaye (2000) estimated the causal relationships between energy consumption and income for India, Indonesia, the Philippines and Thailand, using cointegration and error-correction modeling techniques within the years 1971-1995 and 1973-1995. The results reveal that for Philippines and Thailand there is bidirectional causality hence for India and Indonesia there is unidirectional causality running from energy consumption to economic growth. The causal relationship for Philippines contradict with that of Yu and Choi (1985) which indicated that there was unidirectional causality from energy consumption to economic growth.

Soytas and Sari (2003) reexamined the causality relationship between energy consumption and economic growth for the top 10 emerging markets and G7 countries using cointegration and Granger causality. The empirical results of the study shows that for Turkey, France, Germany and Japan, the causality runs from energy consumption to

GDP while for Argentina there is bidirectional causality and for Italy and Korea there is unidirectional causality running from economic growth to energy consumption.

Lee (2005) reinvestigated the direction of the causality between energy consumption and economic growth in 18 developing countries within the years 1975-2001 using panel unit root, heterogeneous panel cointegration, and panel based error correction models. The study criticizes previous studied in terms of short time ranges which could yield unreliable and inconsistent empirical results thus Lee (2005) employed a contemporary model. The empirical results of the study indicate that both in the short and long run causality runs from energy consumption to economic growth supporting the growth hypothesis.

Wolde-Rufael (2005) investigated the long run relationship between energy use per capita and GDP for 19 African countries within the period 1971-2001 using Bounds testing approach. The benefits of the method lie in the fact that Bounds test does not require the data to be individually or mutually co-integrated. To test the direction of the regression the study also uses Toda and Yamamoto's Granger causality test. The results asserts that for Algeria, Congo, Egypt, Ghana and Ivory Coast the energy conservation hypothesis holds; for Cameron, Morocco, Nigeria the growth hypothesis holds; for Gabon and Zambia the feedback hypothesis holds and for Benin, Congo, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia and Zimbabwe neutrality hypothesis holds.

Soytas and Sari (2006) reanalyzed the impact of a change in energy consumption and income within the framework of the production function for G-7 countries using multivariate cointegration, error correction models, generalized variance decompositions and Granger causality for the years 1960-2004. Unlike the previous study Soytas and Sari (2003), the results indicate that for Germany the causality runs from GDP to energy consumption, for France the studies are similar in supporting the growth hypothesis and for Italy and Japan while Soytas and Sari (2003) found unidirectional causality Soytas and Sari (2006) supported the feedback hypothesis. Furthermore for USA the results indicated a unidirectional causality from energy consumption to economic growth and vice versa for Canada and UK.

Lee (2006) revisited the relationship between energy use and economic growth for the 11 major industrialized countries within the period 1960-2001 using Toda and Yamamoto’s version of Granger causality. The results of the study did not support the neutrality hypothesis thus the findings express that there is bidirectional causality for Sweden and USA, unidirectional causality from energy consumption to economic growth for Belgium, Canada, Switzerland and Netherlands however no causality for Germany and UK. The study reached a similar result for Canada as that of Erol and Yu (1987) however, contradicted with Ghali and El-Sakka (2004). Similarly for Germany the results did not align with Erol and Yu (1987) and Soytas and Sari (2003) moreover for UK the findings were similar with that of Erol and Yu (1987).

Al-Iriani (2006) have analyzed the direction of the causality between energy consumption and GDP for six countries of the Gulf Cooperation Council (GCC) namely; Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates, within the years 1970-2002 using panel cointegration and Granger causality. Al-Iriani (2006) indicates that the empirical results do not support the growth hypothesis for oil exporter countries which obtain cheap oil hence the results support the conservation hypothesis.

Lee and Chang (2007b) applied panel VARs and generalized method of moment (GMM) techniques to the data of 22 developed and 18 developing countries for the purpose of investigating the causal relationship between energy consumption per capita and GDP per capita for the years 1965-2002 and 1971-2002. The empirical results proves the existence of a causality for both group of countries hence there is unidirectional causality running from GDP to energy consumption for developing countries while there is bidirectional causality for developed countries.

Zachariadis (2007) demonstrated the causal relationship between energy consumption and economic growth applying bivariate energy-economy causality tests for the G7 countries; Canada, France, Germany, Italy, Japan, the United Kingdom and the United States for the period 1960-2004. Zachariadis (2007) reaches to a conclusion that different tests such as vector error correction, ARDL and Toda and Yamamoto reveal contradicting results not only on the cross country basis but also for individual countries. The study propounds that only for the USA the three tests align with each other supporting the neutrality hypothesis. Nevertheless, the study does not reach to clear conclusion for other G7 countries regarding the direction of the causality due to the contradictions between test results.

Sari and Soytas (2007) analyzed the causal relationship between energy consumption and economic growth within the framework of a production function for six developing countries Indonesia, Iran, Malaysia, Pakistan, Singapore and Tunisia using generalized variance decompositions and generalized impulse response techniques for the period 1971-2002. The results of the study indicate that energy stands to be a more important input factor of production than labor and that the neutrality hypothesis does not hold for these developing countries yet the clear direction is also not observable due to the different level of significance of energy use.

Akinlo (2008) analyzed the causal relationship between energy consumption and economic growth in the selected 11 sub-Sahara Africa countries for the period 1980-2003 using the ARDL bounds test which has not been used in the previous studies. Based on the vector error correction model there is bidirectional causality for Gambia, Ghana and Senegal. Moreover, Granger causality tests revealed that unidirectional causality runs from economic growth to energy consumption in Zimbabwe, Congo and Sudan. The neutrality hypothesis is supported for Cameroon, Cote d'lvoire, Nigeria, Kenya and Togo.

Chiou-Wei, Chen and Zhu (2008) considered the fact that previous studies have ignored non-linear behavior which could be originated from structural breaks; this study applied both linear and non-linear Granger causality tests to examine the causal relationship between energy consumption and economic growth in selected industrialized Asian countries and USA for the period 1954-2006. Empirical results assert that for USA, Thailand, South Korea the neutrality hypothesis holds; for

Philippines and Singapore the conservation hypothesis holds and for Taiwan, Hong Kong, Malaysia and Indonesia the growth hypothesis holds.

Lee, Chang and Chen (2008) reinvestigated the energy-income causality using panel cointegration and panel vector error correction models for 22 Organization for Economic Co-operation and Development (OECD) countries using data of the years 1960-2001. The study analyzed the relationship and finds strong evidence supporting the cointegration between the series in the long run. “The panel causality test indicates the existence of bi-directional causal linkages among energy consumption, the capital stock and economic growth.” (Lee et.al., 2008: 2371).

Huang, Hwang and Yang (2008) broadened the context of the studies conducted regarding the causal relationship between energy consumption and economic growth to 82 countries for the period 1972-2002 using GMM and Panel VARs to estimate the relationship. The countries were divided into four categories; low, lower middle, upper middle and upper income countries, for ease of analysis. The results of the regression ascertain that for the low income countries there is no causality between the series; for lower and upper middle income countries the causality runs positively from energy consumption to economic growth; finally for the upper income countries the causality runs negatively from economic growth to energy.

Narayan and Smyth (2008) examined the relationship between capital formation, energy consumption and real GDP in G7 countries; Canada, France, Germany, Italy, Japan, UK and USA using panel unit root, panel cointegration and Granger causality between the years 1972-2002. The study asserts that previous studies conducted regarding the G7 countries have reached conflicting results mainly due to the analysis of short time periods. As a result of the regressions, Narayan and Smyth (2008) have found that energy consumption Granger causes economic growth and that capital formation and energy consumption have a positive effect on real GDP.

Lee and Chang (2008) applied the panel unit root, panel cointegration and panel error correction models to reexamine the causal relationship between energy consumption and real GDP within a multivariate framework for 16 Asian countries during 1971-2002. Lee and Chang (2008) propound that “although earlier studies have usually investigated the relationship between energy and GDP from either the demand side or the production side models, in this paper, we argue that energy is indeed an essential factor in production.” (Lee and Chang, 2008: 63). The overall conclusion of the study does not support the neutrality hypothesis yet asserts that energy consumption Granger causes economic growth in the long run. Moreover there is no evidence presenting a causality running from economic growth to energy consumption in the short.

Chontanawat, Hunt and Pierse (2008) enhanced the context of the energy-economy causality relationship to a range of 100 countries among which 30 of them OECD and 78 non-OECD countries using Granger causality for the period 1960-2000. The study reached to diversified conclusions which contradict with the previous studies and provisions and asserting that “causality from energy to GDP is generally less prevalent in the developing world than the developed world, thus supporting the view that energy is generally neutral with respect to its effect on economic growth in the developing world.” (Chontanawat et.al., 2008: 218)

Wolde-Rufael (2009) reexamined the causal relationship between energy consumption and economic growth for selected 17 African countries within the framework of a production function including capital and labor using variance decomposition and Toda and Yamamoto’s version of Granger causality for the period 1971-2004. The results of the analysis reject the neutrality hypothesis in fifteen of the countries yet supports the conservation hypothesis for Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia and Zambia; growth hypothesis was supported for Algeria, South Africa and Benin, feedback hypothesis was supported for Gabon, Ghana, Togo and Zimbabwe. In the remaining two countries Cameroon and Kenya no evidence regarding the causality was observed.

Mishra, Sharma and Smyth (2009a) applied panel stationarity tests to analyze the stationarity of the energy consumption per capita for 13 Pacific countries within the period 1980-2005. The study indicates that the test applied differentiates from other studies in terms of allowing multiple structural breaks which matters when deciding whether a series is stationary or not. The result of the study reveals that energy consumption per capita for nearly 60% of the countries are stationary. Furthermore, Mishra, Smyth and Sharma (2009b) extended the analysis and tested the series using Granger causality and provided evidence regarding the causal relationship between energy consumption and economic growth. As a result of the study, Mishra et.al. (2009b) propound that there is bidirectional causality.

Apergis and Payne (2009a) examined the causal relationship between energy consumption and economic growth in six Central American countries for the period 1980-2004 using panel cointegration and error correction model. Empirical results suggest that in the long run an increase in energy consumption increases real GDP and the estimation of panel vector error correction model reveals evidence of a causality running from energy consumption to economic growth both in the long and short run.

Apergis and Payne (2009b) investigated the relationship between energy consumption and economic growth for 11 Commonwealth Independent States (CIS) for the period 1991-2005 using heterogeneous panel cointegration test and error correction model. The estimations show cointegration between real GDP, energy consumption, gross fixed capital formation and labor. The corresponding Granger causality tests reveal that there is unidirectional causality supporting the growth hypothesis in the short run while bidirectional causality in the long run. Bearing in mind both the short and long run the overall conclusion of the study is supporting the feedback hypothesis.

Apergis and Payne (2009c) examined the causal relationship between carbon dioxide emissions, energy consumption and economics growth for six Central American countries within the period of 1971-2004 using panel vector error correction model. The empirical results of the study reveal that in the long run energy consumption and carbon emission are positively co-integrated and that there is bidirectional causality. On the other hand the short run results indicate that there is unidirectional causal relationship from energy consumption and real output to carbon emissions.

Balcilar, Ozdemir and Arslanturk (2010) dwelled on the facts that lead to diverse conclusions in the literature regarding the causal direction between energy consumption and economic growth such as the sample sizes, country specific effects, differences in the methodology and tries to overcome these aspects using bootstrap Granger non-causality with fixed sized rolling samples for G7 countries between the years 1960-2006. The estimation results indicate that only for Canada there is strong evidence supporting causality running from energy consumption to economic growth. Although, the overall findings from the bootstrap rolling window estimation show no causal relationship between energy consumption and economic growth, the series in some subsamples which are associated with various economic changes, indicate that there is causal relationship. The concluding results support the neutrality hypothesis.

Ozturk, Aslan and Kalyoncu (2010) applied panel cointegration test to investigate the relationship between energy consumption and economic growth followed by panel Granger causality tests to examine the direction of the causal relationship for 51 countries between the years 1971-2005. The study divides the 51 countries into three categories namely; lower income, lower middle income and upper middle income countries. "The empirical results of panel cointegration test show that energy consumption and GDP are cointegrated for all three income groups. In addition, panel causality test results reveal that there is a long-run Granger causality running from GDP to energy consumption for low income countries and bidirectional Granger causality between energy consumption and GDP for the lower middle and upper middle income countries" (Ozturk et.al., 2010: 4427).

Odhiambo (2010) applied the ARDL bounds test and Granger causality to 1972-2006 data for three Sub-Sahara African countries namely South Africa, Kenya and Congo in order to test the causal relationship between energy consumption and economic growth. The results of the test indicate that there is causality present between the series yet varies significantly among countries. For South Africa and Kenya the study supports the growth hypothesis and for Congo the conservation hypothesis.

Acaravci and Ozturk (2010) studied the causal relationship between energy consumption, CO_2 emissions and economic growth using ARDL bounds testing and Granger causality in selected European countries; Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and UK, for the period 1970-2005 for Germany, 1965-2005 for Hungary and 1960-2005 for the remaining. The study ascertains that there is long run unidirectional causality running from energy consumption per capita and real GDP per capita to carbon emissions per capita in Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland and short run unidirectional causality from real GDP per capita to carbon emissions in Denmark and Italy. Furthermore, there is short run unidirectional causality running from real GDP per capita to energy consumption per capita in Italy and Greece and, there is bidirectional causality between real GDP per capita and energy consumption in Switzerland.

Constantini and Martini (2010) analyzed the causal relationship between economic growth and energy consumption using vector error correction models with non-stationary cointegrated panel data of 71 developed and developing countries within the period 1960-2005. Even though the direction of the causality varies within the sample countries and sectors, in the short run there is unidirectional causality supporting the conservation hypothesis on the other hand in the long run there is bidirectional causality supporting the feedback hypothesis.

Apergis and Payne (2010a) examined the causal relationship between carbon dioxide emissions, energy consumption and economics growth for the eleven CIS within the period 1992-2004 using a panel vector error correction model. The study refers to the Environmental Kuznets Curve (EKC) and states that in the long run economic growth follows the corresponding inverted U-shaped curve. Apergis and Payne (2010a) support the previous studies in terms of the significant impact of energy consumption on carbon dioxide emissions with bidirectional causality. Furthermore, the empirical results indicate that in the short run there is a unidirectional causality running from energy consumption and economic growth to carbon emissions and, bidirectional causality between energy consumption and economic growth in the long run.

Apergis and Payne (2010b) analyzed the causal relationship between renewable energy consumption and economic growth for 20 panel OECD countries within the years 1985-2005 within a multivariate framework using panel cointegration and error correction models. The heterogeneous panel cointegration tests reveal that there is long run equilibrium relationship between the series and the Granger causality test indicates that there exists bidirectional causality between renewable energy consumption and economic growth.

Apergis and Payne (2010c) studied the energy consumption and economic growth nexus in nine countries of South America for the period 1980-2005 using a panel cointegration and error correction model within a multivariate framework. “Pedroni's heterogeneous panel cointegration test reveals there is a long-run equilibrium relationship between real GDP and energy consumption furthermore; the estimation of a panel vector error correction model indicates the presence of both short-run and long run unidirectional causality from energy consumption to economic growth.” (Apergis and Payne, 2010c: 1425)

Sharma (2010) used dynamic panel data models to interpret the causal relationship between energy use and economic growth for a panel of 66 countries constitute of four panels namely East/South Asian and the Pacific region, Europe and Central Asian region, Latin America and Caribbean region, and Sub-Saharan, North Africa and Middle Eastern region for the period 1986-2005. For East/South Asian and Pacific region, Europe and Central Asian region, Latin America and Caribbean region there is causality running from energy consumption to economic growth and for Sub Saharan, North Africa and Middle Eastern region the causality runs from economic growth to energy consumption. However the overall results do not indicate unity.

Pao and Tsai (2010) analyzed the dynamic causal relationship between CO_2 emissions, energy consumption and economic growth for the BRIC countries (Brazil, Russia, India, China) within the period 1971-2005 using the vector error correction and

VAR models. The study indicates that energy consumption has a significant effect on the pollutant emissions with strong bidirectional causality and that the output shows an inverted U-shaped curve associated with the EKC hypothesis. Furthermore the empirical results indicate that there is strong bidirectional causality between energy consumption and carbon emissions and, bidirectional causality between energy consumption and economic growth.

Ozturk and Acaravci (2010b) implemented two steps Engle and Granger causality model which the first step uses the ARDL bounds testing and the second step uses the vector error correction model in order to test the causal relationship between energy consumption and economic growth in Albania, Bulgaria, Hungary and Romania within the years 1980-2006. The results of the bonds test put forth that there is long run relationship amongst the series and bidirectional causality for Hungary. On the other hand for Bulgaria, Albania and Romania, the ARDL bounds test yield no evidence towards a long run relationship moreover no causality was observed.

Kebede, Kagochi and Jolly (2010) analyzed the impact of energy consumption on the economic development in Central, East, West and South regions of the Sub-Saharan Africa within the years 1980-2004 using a two step procedure which the first step is the ordinary least square regression and the second is the first order auto-regression. The regression results indicate that there is a positive relationship between energy use and economic development nevertheless it is not clear what the direction of the relation lays whether energy use causes economic growth or vice versa.

Pao and Tsai (2011) examined the impact of financial development, economic growth and energy consumption on CO_2 emissions for the BRIC countries within the years 1980-2007 using panel vector error correction models and Granger causality tests. The results indicate strong bidirectional causality between energy consumption and pollutant emissions. In the short run there is bidirectional causality between energy use and economic growth while in the long run there is unidirectional causality from energy consumption to economic growth.

Apergis and Payne (2011) reexamined the relationship between renewable energy consumption and economic growth in Central America over the period 1980-2006 using heterogeneous panel cointegration test and panel error correction models. The empirical results presents evidence of long run equilibrium relationship between real GDP and renewable energy consumption while, the panel error correction tests indicate bidirectional causality both in the short and long run.

Belke, Dobnik and Dreger (2011) applies dynamic panel causality and Johansen cointegration test in order to examine the long run equilibrium relationship between energy use and economic growth within the years 1981-2007 for 25 OECD countries. The empirical analysis indicate that the long run equilibrium relationship is mainly affected by the international developments suggesting that national energy policies may not have the expected feedbacks due to any divergence in the international equilibrium of energy prices. Furthermore the causality tests reveal that there exists bidirectional causality between energy consumption and economic growth.

In the literature a consensus is yet be reached on the nexus between energy consumption, economic growth and carbon dioxide emissions regarding the direction of the causality between the series. Although there is a wide range of methodologies in the area, dynamic panel data models (Sharma, 2010 and Belke et.al., 2011) is a contemporary method to reanalyze the relationship and this study in the next section will analyze the causal relationship using dynamic panel data, more specifically Arellano and Bond (1991) Generalized Method of Moments (GMM) estimator.

Table 3-2 Summary of the Multi-Country Specific Studies

Study	Periods	Country	Methodology	Causal Relationship
Yu and Choi (1985)	1950-1976	5 Countries	Granger Causality	GDP --- EC (UK, USA, Poland) EC--> GDP (Phillippines) GDP --> EC (Korea)
Erol and Yu (1987)	1952-1982	6 Industrialized Countries	Granger Causality	GDP <--> EC (Japan) GDP --> EC (Italy, Germany) EC --> GDP (Canada) GDP --- EC (France, UK)
Nachane et al. (1988)	1950-1985	16 Countries	SIM's Technique,Cointegration, Granger Causality	GDP <--> EC (except Venezuela, Colombia)
Masih and Masih (1996)	1955-1990	6 Asian countries	Johansen-Juselius Cointegration, VEC Modeling	GDP --- EC (Malaysia, Philippines, Singapore) EC --> GDP (India) GDP --> EC (Indonesia) GDP <--> EC (Pakistan

Glasure and Aie-Rie (1997)	1961-1990	South Korea and Singapore	Cointegration, VEC	GDP --- EC (South Korea) GDP <-- EC (Singapore)
Asafu-Adjaye (2000)	1973-1995	India, Indonesia, Philippines and Thailand	Cointegration, VEC	EC <--> GDP (Philippines, Thailand) EC --> GDP (India, Indonesia)
Soytas and Sari (2003)	1950-1997	G7 Countries	Cointegration, Granger Causality	GDP <--- EC (Turkey, France, Germany, Japan) EC <--> GDP (Argentina) GDP --> EC (Italy, Korea)
Lee (2005)	1975-2001	18 Developing Countries	Panel ECM	EC --> GDP
Wolde-Rufael (2005)	1971-2007	19 African Countries	Toda and Yamamoto's Granger causality	GDP --> EC (Algeria, Congo, Egypt, Ghana, Ivory Coast) EC --> GDP (Cameron, Morocco, Nigeria) GDP <--> EC (Gabon and Zambia) GDP --- EC (for Benin, Congo, Kenya, Senegal, South Africa, Sudan, Togo, Tunisia, Zimbabwe)
Soytas and Sari (2006)	1960-2004	G7 Countries	Cointegration, VEC, Variance Decomposition	EC --> GDP (France, USA) GDP --> EC (Germany) GDP <--> (Italy, Japan, Canada, UK)
Lee (2006)	1960-2001	11 Industrialized Countries	Toda and Yamamoto's Granger causality	GDP --- EC(Germany,UK) EC <--> GDP (Sweeden, USA) EC --- GDP (Belgium,Netherlands,Canada,Switzerland)
Al-Iriani (2006)	1970-2002	6 GCC Countries	Panel ECM, Granger Causality	GDP --> EC
Lee and Chang (2007b)	1965-2002 1971-2002	22 Developed countries, 18 Developing Countries	Panel VAR, GMM	GDP --> EC (Developing Countries) GDP <--> EC (Developed Countries)
Zachariadis (2007)	1960-2004	G7 Countries	VECM, ARDL, Toda and Yamamoto's Granger causality	GDP --- EC (Only for USA)
Sari and Soytas (2007)	1971-2002	6 Developing Countries	Variance Decompositions and Generalized Impulse Response Techniques	GDP --- EC does not hold yet direction not clear
Akinlo (2008)	1980-2003	11 sub-Sahara Africa Countries	ARDL Bounds Test	GDP <--> EC (Gambia, Ghana, Senegal) GDP --> EC (Zimbabwe, Congo, Sudan) GDP --- EC (Cameroon, Cote d'Ivoire, Nigeria, Kenya, Togo)
Chiou-Wei et al. (2008)	1954-2006	Asian Countries, USA	Linear and Non-linear Granger Causality	GDP --- EC (USA, Thailand, South Korea) GDP --> EC (Philippines and Singapore) EC -->GDP (Taiwan, Hong Kong, Malaysia and Indonesia)
Lee et al. (2008)	1960-2001	22 OECD Countries	Panel ECM, Panel Cointegration	GDP <--> EC
Huang et al. (2008)	1972-2002	82 Countries	Panel VAR, GMM	GDP --- EC (Low Income Countries) EC --> GDP (Middle and High Income Countries)
Narayan and Smyth (2008)	1972-2002	G7 Countries	Panel Cointegration, Granger Causality	EC --> GDP
Lee and Chang (2008)	1971-2002	16 Asian Countries	Panel ECM, Panel Cointegration	EC --> GDP (Long-run) EC --- GDP (Short-run)
Wolde-Rufael (2009)	1971-2004	17 African Countries	Toda and Yamamoto's Granger causality	GDP --> EC (Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia and Zambia) EC --> GDP (Algeria, South Africa, Benin) EC <--> GDP(Gabon, Ghana, Togo, Zimbabwe) EC --- GDP (Cameroon, Kenya)
Mishra et al.(2009a,b)	1980-2005	13 Pacific Countries	Granger Causality	GDP <--> EC
Apergis and Payne (2009a)	1980-2004	6 Central American Countries	Panel ECM, Panel Cointegration	EC --> GDP
Apergis and Payne (2009b)	1991-2005	11 CIS Countries	Panel ECM, Panel Cointegration	EC --> GDP (Short-run) GDP <--> EC (Long-run)
Apergis and Payne (2009c)	1971-2004	6 Central American Countries	Panel ECM, Panel Cointegration	EC <--> GDP

Balcilar et al.(2010)	1960-2006	G7 Countries	Bootstrap Granger non-Causality	EC --- GDP
Ozturk et al. (2010)	1971-2005	51 Countries	Panel Cointegration	GDP --> EC (Low Income Countries) GDP <--> EC (Lower Middle and Upper Middle Income Countries
Odhiambo (2010)	1972-2006	Sub-Saharan African Countries	ARDL Bounds Test	GDP <-- EC (South Africa, Kenya) GDP --> EC (Congo)
Acaravci and Ozturk (2010)	1970-2005	European Countries	ARDL Bounds Test	GDP --> EC (Italy, Greece) GDP <--> EC (Switzerland)
Constantini and Martini (2010)	1960-2005	71 Developed Countries	Panel ECM, Panel Cointegration	GDP --> EC (Short-run) GDP <--> EC (Long-run)
Apergis and Payne (2010a)	1992-2004	11 CIS Countries	Panel ECM, Panel Cointegration	EC --> GDP (Short-run) GDP <--> EC (Long-run)
Apergis and Payne (2010b)	1985-2005	20 OECD Countries	Panel ECM, Panel Cointegration	GDP <--> EC
Apergis and Payne (2010c)	1980-2005	9 Countries of South America	Panel ECM, Panel Cointegration	EC --> GDP
Sharma (2010)	1986-2005	66 Countries	DPD Models	EC --> GDP (East/South Asian and Pacific region, Europe and Central Asian region, Latin America and Caribbean region) GDP --> EC (Sub Saharan, North Africa and Middle Eastern region)
Pao and Tsai (2010)	1971-2005	BRIC Countries	VECM, VAR	EC <--> GDP
Ozturk and Acaravci (2010b)	1980-2006	Albania, Bulgaria, Hungary and Romania	ARDL Bounds Test, VECM	EC <--> GDP (Hungary) EC --- GDP (Bulgaria, Albania, Romania)
Pao and Tsai (2011)	1980-2007	BRIC Countries	Panel ECM, Granger Causality	EC <--> GDP (Short-run) EC --> GDP (Long-run)
Apergis and Payne (2011)	1980-2006	Central america	Panel ECM, Panel Cointegration	GDP <--> EC
Belke et al. (2011)	1981-2007	25 OECD Countries	DPD Models, Johansen Cointegration	GDP <--> EC

PART FOUR

METHODOLOGY, DATA AND ANALYSIS

4. Economic Method

4.1. Data and Methodology

The study works on the annual data on per capita total primary energy consumption in kilogram of oil equivalent (kgoe), per capita GDP in constant 2000 US$ and per capita CO_2 emissions in metrictons (mt) between the years 1997 and end of 2008 for 13 newly EU members of CEE and candidate countries. These countries are Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovak Republic, Slovenia, Hungary, Bulgaria, Romania, Turkey, Macedonia FYR and Croatia. The main source of the data is the World Bank database World Development Indicators (WDI) moreover the data have been complemented from U.S. Energy Information Administration (EIA) and International Energy Agency (IEA).

The seminal article about causality depicts that "if Y_t contains information in the past terms that helps in the prediction of X_t and if this information is contained in no other series used in the predictor, then Y_t is said to cause X_t." (Granger, 1969: 430). In this sense, if energy consumption is good for growth, than it should cause growth with a positive sign. Similarly, if economic growth is fueled by energy consumption, than increasing economic growth would cause energy consumption as well with a positive sign. The same hypotheses are also valid for the nexus between GDP growth and CO_2 emissions. In this regard Granger causality running from Y_t to X_t can be tested by regressing X_t on its own lags and on the lags of Y_t as well. If the lags of Y_t are statistically significant than the hypothesis indicating Y_t Granger causes X_t cannot be rejected. The same method is followed to investigate the inverse causal relationship running from X_t to Y_t.

In this study a dynamic panel data model has been used where the lagged levels of both economic growth and energy consumption for model 1a, lagged levels of economic growth and carbon emissions for model 2a and lagged levels of energy consumption and carbon emissions for model 3a have been taken into account by using the Arellano and Bond (1991) GMM estimator. Main problem faced when using the Arellano and Bond (1991) GMM is the fact that it is relevant under the circumstances that the panel contains smaller time period and large cross section. The panel used in this study fulfills this restriction with 13 cross sections and 12 year time span. The model basically will be in the form as follows (Holtz-Eakin, Newey and Rosen, 1988: 1372);

Base Model[4]:

$$\mathrm{Y_t} = \beta_0 + \sum_{l=1}^{m} \beta_l Y_{it-l} + \sum_{l=1}^{m} \theta_l X_{it-l} + v_i + u_{it}$$

Here the country specific effects, v_i is included into the regression however another problem encountered is that these effects may be correlated with the explanatory variables which creates an endogeneity problem. The fixed effects v_i and the observation specific effects e_{it} are contained in the error term u_{it} such that;

$$u_{it} = v_i + e_{it}$$

$$E[v_i] = E[e_{it}] = E[v_i e_{it}] = 0$$

In dynamic panel data models the first step to eliminate the endogeneity problem is to adapt the data by taking the first difference of all the variables thus eliminating the individual effects and the constant term which transforms the model into;

$$\Delta Y_t = \sum_{l=1}^{m} \beta_l \Delta Y_{it-l} + \sum_{l=1}^{m} \theta_l \Delta X_{it-l} + \Delta u_{it}$$

It is common in the test of Granger causality that the causal relationship runs in both directions moreover, the purpose of the study is to identify the direction of the causality between energy consumption, economic growth and carbon dioxide emissions thus the estimations will be analyzed inversely as well in model 1b, 2b and 3b. The boundary of the study is limited with 13 cross sections and 12 years time period thus the

[4] The variables will be in their natural logarithmic values.

panel corresponds to 156 observations. Furthermore the Granger causality tests require the data to be stationary thus the time series will be tested for the presence of unit roots applying the standard panel unit roots tests.

It is also important to determine an optimal lag for the model thus the time stationary VAR Base Model has been estimated using the OLS estimation technique and based the lag selection on the Akaike Information Criteria. The results yielded assert that the optimal leg length two ($m = 2$) even though it is not necessary to use the same lag length for both X_{it-l} and Y_{it-l} in this model it is assumed the same.

Model 1a where Y is the GDP and X is the energy consumption for N countries indexed by i, over T periods indexed by t; i = 1…13 and t = 1…12,

$$\Delta Y_t = \sum_{l=1}^{m} \beta_l \Delta Y_{it-l} + \sum_{l=1}^{m} \theta_l \Delta X_{it-l} + \Delta u_{it}$$

and the inverse causality test for model 1b;

$$\Delta X_t = \sum_{l=1}^{m} \psi_l \Delta X_{it-l} + \sum_{l=1}^{m} \gamma_l \Delta Y_{it-l} + \Delta w_{it}$$

For model 1a the null hypothesis that will be tested is that $H_0 : \theta_l = 0$ which corresponds to the result that X in this case energy consumption does not cause Y, economic growth and the alternative hypothesis is that $H_1 : \theta_l \neq 0$ that implies energy consumption causes economic growth. And for model 1b; $H_0 : \gamma_l = 0$ and $H_1 : \gamma_l \neq 0$

Model 2a where carbon dioxide emission is indexed by C;

$$\Delta Y_t = \sum_{l=1}^{m} \delta_l \Delta Y_{it-l} + \sum_{l=1}^{m} \varphi_l \Delta C_{it-l} + \Delta \eta_{it}$$

$H_0 : \varphi_l = 0$ and $H_1 : \varphi_l \neq 0$

and the inverse causality test for model 2b;

$$\Delta C_t = \sum_{l=1}^{m} \phi_l \Delta C_{it-l} + \sum_{l=1}^{m} \varsigma_l \Delta Y_{it-l} + \Delta \rho_{it}$$

$H_0: \varsigma_l = 0$ and $H_1: \varsigma_l \neq 0$

Model 3a which analyzes the relationship between energy consumption and CO_2 emissions;

$$\Delta X_t = \sum_{l=1}^{m} \lambda_l \Delta X_{it-l} + \sum_{l=1}^{m} \sigma_l \Delta Y_{it-l} + \Delta \varpi_{it}$$

$H_0: \sigma_l = 0$ and $H_1: \sigma_l \neq 0$

and the inverse causality test from model 3b;

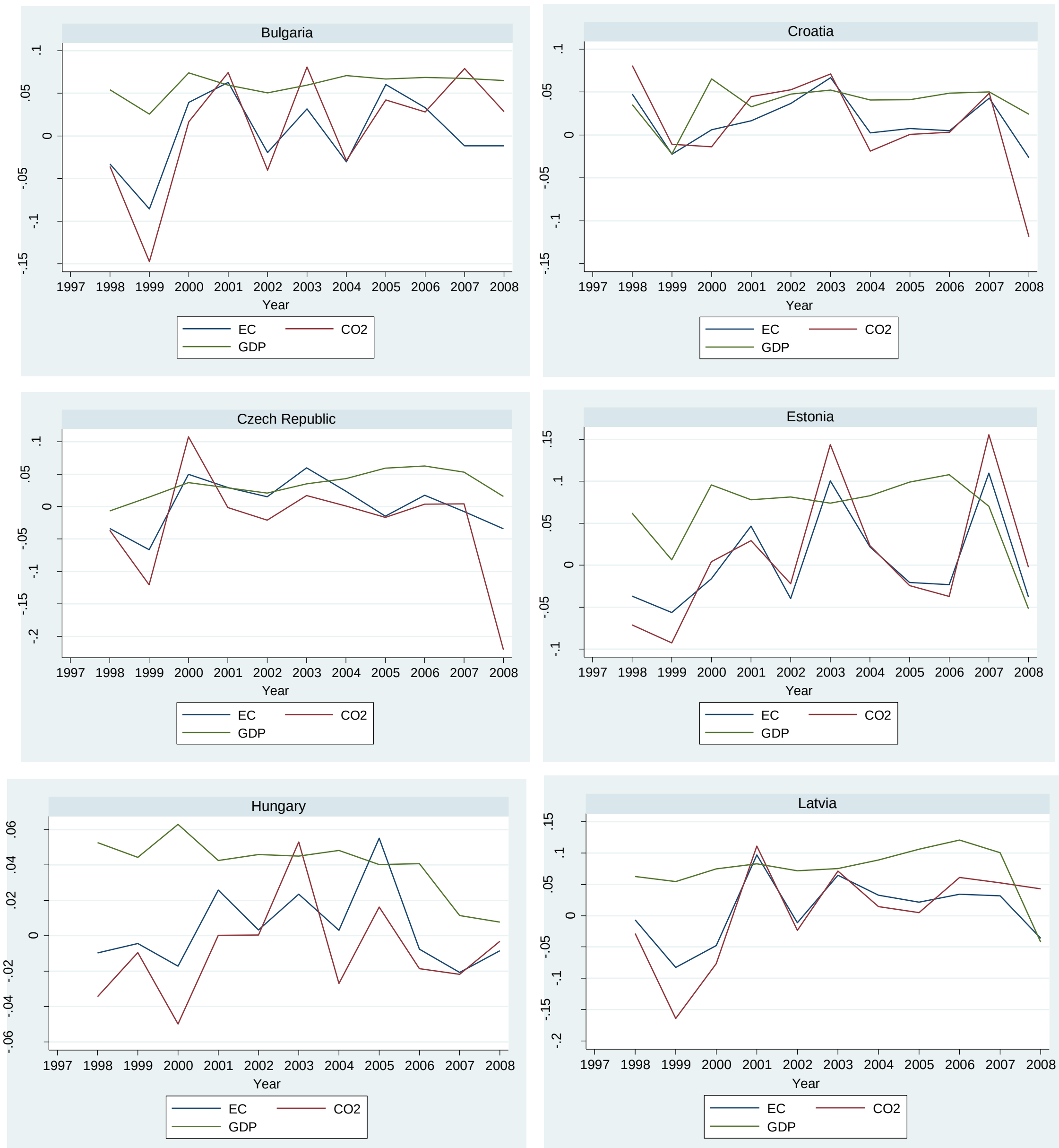
$$\Delta C_t = \sum_{l=1}^{m} \omega_l \Delta X_{it-l} + \sum_{l=1}^{m} \xi_l \Delta Y_{it-l} + \Delta \tau_{it}$$

$H_0: \xi_l = 0$ and $H_1: \xi_l \neq 0$

4.2. Empirical Analysis and Results

The first step in the empirical analysis most commonly is to analyze the data in the form of graphs. Figure 4-1 demonstrates the line plots of the per capita GDP, per capita energy consumption (EC) and per capita CO2 emissions for the sample 13 countries between 1997 and 2008. Analyzing the line plots for each country individually the trends of all the variables seems to be similar. In most of the countries the fluctuations of per capita GDP, energy consumption and carbon dioxide emissions along time resemble a cointegration relationship. While the energy consumption and carbon dioxide emissions show a nearly perfect co-movement for all countries, only for Turkey the same patter can be observed when GDP is also included into the analysis. It can be observed from the line plots that when countries' abundant energy source changes the corresponding fluctuations in CO_2 are visible, for instance for Slovak Republic in 1998 two nuclear power plants were started operating and bearing in mind that nuclear energy has the lowest carbon gas emissions, from the figure it is clear that the CO_2 emissions per capita has dropped dramatically until the EU member accessions start during the year 2000 in times which the nuclear power plants were being decommissioned according to the EU accession requirements thus the CO_2 emissions starts to rise again.

Figure 4-1[5] Line plots of CO_2 emissions, GDP and EC 13 countries



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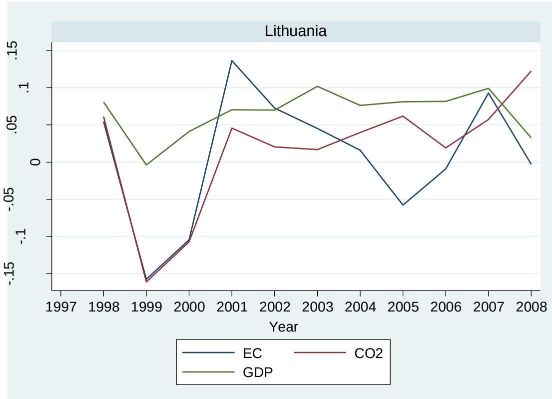
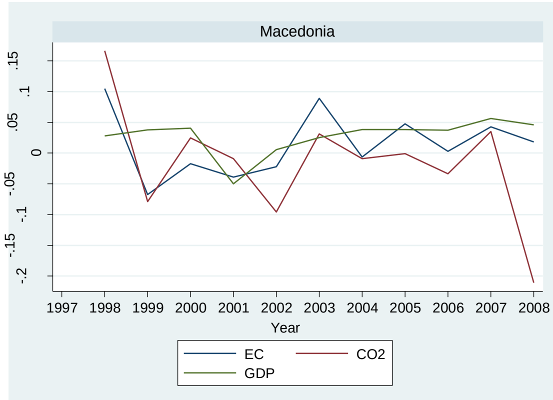
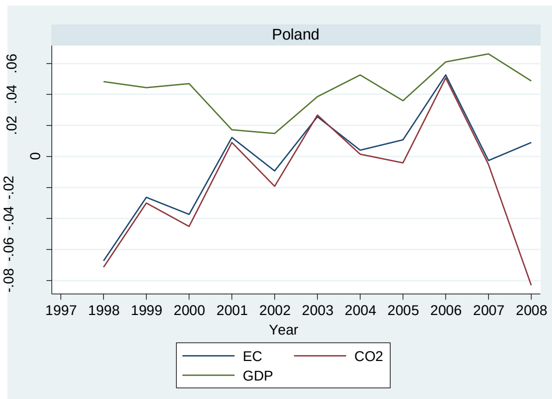
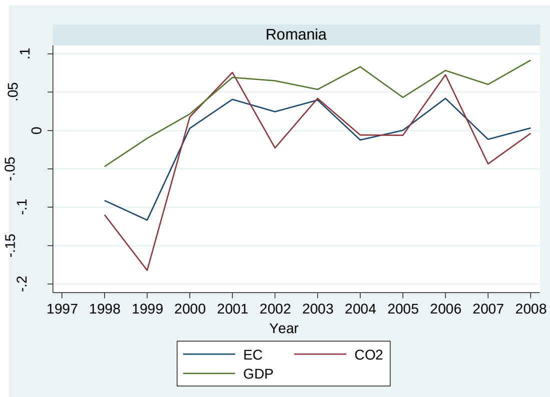
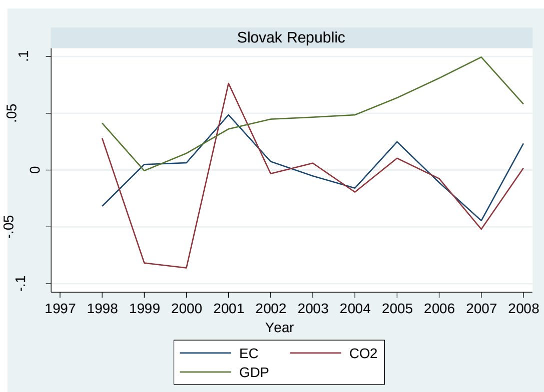
[5] The variables are per capita values; per capita GDP, per capita energy consumption and per capita carbon dioxide emissions. The values are in natural logarithms and first differenced in order to eliminate the unit root.

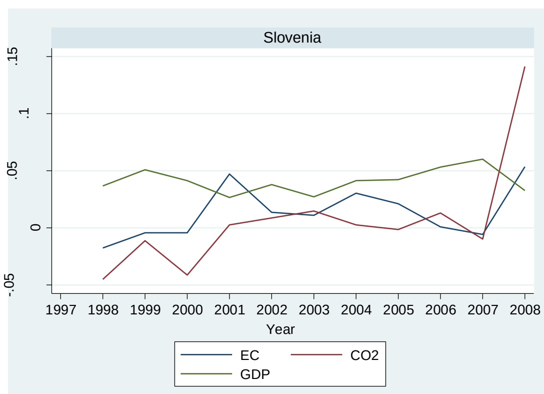

Lithuania
-.15 -.1 -.05 0 .05 .1 .15
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP

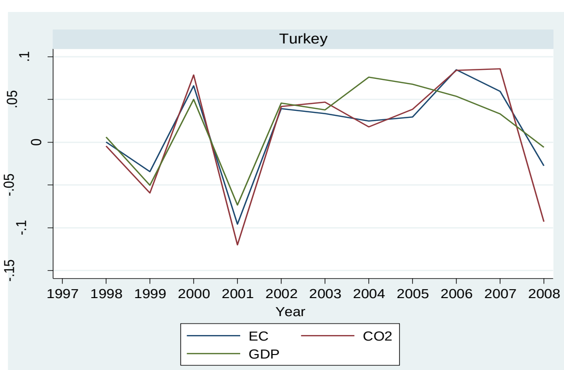

Macedonia
-.2 -.15 -.1 -.05 0 .05 .1 .15
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP


Poland
-.08 -.06 -.04 -.02 0 .02 .04 .06
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP


Romania
-.2 -.15 -.1 -.05 0 .05 .1
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP


Slovak Republic
-.1 -.05 0 .05 .1
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP


Slovenia
-.05 0 .05 .1 .15
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP


Turkey
-.15 -.1 -.05 0 .05 .1
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Year
EC
CO2
GDP

In order to test the Granger causality between energy consumption, GDP growth and carbon dioxide emissions, the three series are required to be stationary as previously defined. Preliminary panel unit root tests for the data indicate that there is unit root thus the data is required to be transformed by taking the first difference. Table 4-1 presents the following panel unit root tests which clearly show that the test results reject the null hypothesis of non-stationarity for the three series.

Table 4-1 Panel unit root test results (13 countries, 1999-2008)

H_0 : Unit root in level	GDP			EC			CO_2		
	Stat.	Prob.	Obs.	Stat.	Prob.	Obs.	Stat.	Prob.	Obs.
Levin, Lin & Chu t*	-3.184	0.000	143	-6.067	0.000	143	-5.054	0.000	143
Im, Pesaran & Shin W-stat	-2.151	0.015	143	-4.563	0.000	143	-4.541	0.000	143
ADF - Fisher Chi-square	51.744	0.001	143	82.074	0.000	143	84.749	0.000	143
PP - Fisher Chi-square	51.744	0.001	143	82.074	0.000	143	84.749	0.000	143

Per capita total primary energy consumption in kilogram of oil equivalent (kgoe), per capita GDP in constant 2000 US$ and per capita CO_2 emissions in metrictons (mt) Time trends are included. For the entire tests presented above the maximum lags are automatically selected based on Akaike Information Criterion. Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Table 4-2 presents the estimation results for the model 1a with OLS, Arellano-Bond one-step GMM and Arellano-Bond two-step GMM. The OLS estimation includes fixed country specific effects. Furthermore the GMM estimation includes period specific effects, lags of both the dependent and independent variable for model 1a lags of GDP and EC for at least 2 lags. The function of “computing two-step estimator instead of one” of the statistics software STATA v11 is used to compute two-step GMM. Furthermore the Table 4-2 also gives the estimation results for the Wald test, Sargan test which tests whether the instruments, in this case the lags, are uncorrelated with the error term u_{it} and the Arellano-Bond test (AB test).

The OLS, Arellano-Bond one-step GMM and two-step GMM estimations consistently present negative and statistically significant first lag coefficients for energy consumption. Moreover the Arellano-Bond one-step GMM estimation results for second lagged coefficient of energy consumption is positive and statistically significant as well.

For OLS estimation, Wald test rejects the null hypothesis that the coefficients of lagged per capita energy consumption are jointly equal to zero at 10% significance level and, Arellano-Bond one-step and two-step estimations both reject the null hypothesis at 5% significance level. In this context it is logical to state that per capita energy consumption Granger-causes per capita GDP with a negative impact for the first lagged coefficients and with a positive impact for the second lagged coefficients.

Table 4-2 Estimation Results for Model 1a

	GDP – EC		
	(1) OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
GDP(-1)	0.352*** (0. 104)	0.371*** (0.099)	-1.161 (0.300)
GDP(-2)	0.165 (0.103)	0.098 (0.099)	0.176 (1.166)
EC(-1)	-0.147** (0.061)	-0.146** (0.070)	-0.152** (0.060)
EC(-2)	0.021 (0.061)	0.118* (0.071)	-0.022 (0.075)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.051	0.030	0.014
Sargan Test (ρ-level)	-	0.002	0.002
AB test (ρ-level)	-	0.663	0.310

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

Furthermore the AB test does not reject the hypothesis stating that there is no second order autocorrelation in the first differenced equation. On the other hand the results for Sargan test for overidentifying restrictions reject the null hypothesis stating that the instruments are valid in a sense that they are not correlated with the errors in the first differenced equation. Rejecting the null hypothesis indicates that the instruments, in this case the lagged levels are not valid nevertheless, Sargan (1958) states in his article that the high number of instruments may decrease the accuracy of the estimates “the use of large numbers of instrumental variables may not improve the accuracy of the estimates” (Sargan, 1958: 414). Furthermore Roodman (2006) also supports the statement and asserts that "the Sargan/Hansen test should not be relied upon too faithfully, as it is prone to weakness". (Roodman, 2006: 13)

Moreover, Bowsher (2002) analyzes the accuracy of the Sargan test with different time series dimensions (T) ranging from 5 to 15 and finds out that "Sargan test behaves very poorly for high values of T" (Bowsher, 2002: 215). Considering the fact that the number of instruments and time series dimension used in this study is high, taking the Sargan test into account may yield biased conclusions. In this regard the Sargan Test will not be considered when reaching a conclusion.

Table 4-3 Estimation Results for Model 1b

	EC – GDP		
	(1) OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
GDP(-1)	0.184 (0. 141)	-0.082 (0.097)	-0.126* (0.066)
GDP(-2)	-0.169 (0.140)	-0.119 (0.099)	-0.057 (0.085)
EC(-1)	-0.077 (0.083)	0.262 (0.227)	0.433* (0.230)
EC(-2)	-0.123 (0.082)	-1.138 (0.228)	-0.266* (0.145)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.348	0.511	0.068
Sargan Test (ρ-level)	-	0.423	0.423
AB test (ρ-level)	-	0.534	0.597

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

Before jumping to an inference regarding the estimation results of model 1a, it is necessary to test whether or not the causality runs from GDP to energy consumption as well. From Table 4-3 which presents the estimation results of model 1b, it is clear that the Wald test results do not reject the null hypothesis that the coefficients of lagged per capita GDP are jointly equal to zero thus it is safe to state that GDP does not Granger-cause energy consumption. Both the OLS and Arellano-Bond two-step GMM estimations for model 1a provide evidence with statistically significant coefficients towards a causality running from energy consumption to GDP with a negative effect.

For model 1b while OLS supports the findings of one-step GMM; two-step GMM and the corresponding Wald test with statistically significant coefficients at 10% level designates that there is in fact a causality running from GDP to energy consumption.

Overall the Arellano-Bond one-step GMM and Wald test estimations indicate that there is unidirectional causality running from energy consumption to GDP, nevertheless the identity of the relationship is a negative one for the first lag of per capita energy consumption values which can be inferred as; an increase in the energy consumption of the previous year will lead to a decrease in today's per capita GDP. Within this context this study supports the growth hypothesis however, in a negative direction. This leads to the inference that energy conservation policies would not harm GDP in fact policies towards domestic energy production and decreasing energy imports would improve economic growth.

Table 4-4 Estimation Results for Model 2a

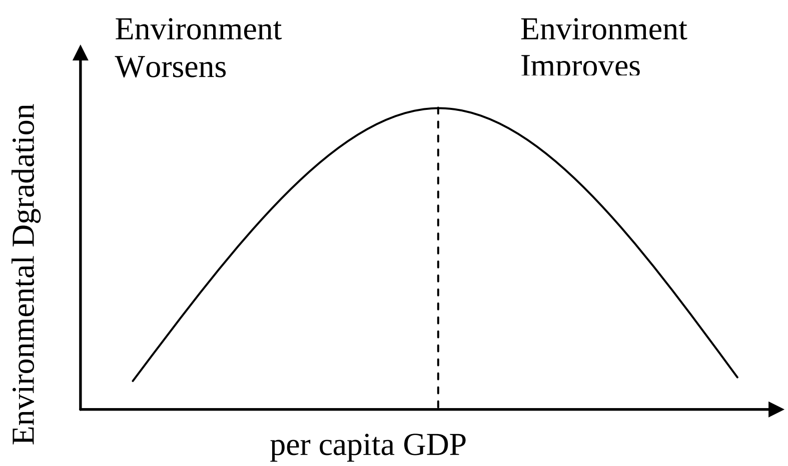
	GDP – CO_2		
	(1)OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
GDP(-1)	0.368*** (0. 103)	0.396*** (0.103)	0.464** (0.155)
GDP(-2)	0.220** (0.104)	0.091 (0.108)	0.176* (0.164)
CO_2(-1)	-0.148** (0.048)	-0.132** (0.580)	-0.154** (0.049)
CO_2 (-2)	-0.018 (0.048)	0.110* (0.062)	0.100** (0.033)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.009	0.011	0.000
Sargan Test (ρ-level)	-	0.008	0.008
AB test (ρ-level)	-	0.596	0.746

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

Considering the fact that all the sample countries are mainly transition and developing economies which are dependent on imports in terms of energy thus a negative sign denoting that energy consumption has a negative impact on GDP is reliable. Due to the fact that imports are inversely related to GDP and for the sample countries energy is an import good therefore an increase in energy demand indirectly decreases per capita GDP.

CO_2 as previously depicted is a byproduct of the use of fossil fuels which is considered as a primary air pollutant. With the shift from agricultural to industrial societies brought about the increase in the use of fossil fuels which in return increased the CO_2 emissions. In this regard there it is clear that there is a direct or indirect relationship between carbon dioxide emissions and economic growth. In the literature the impacts of carbon dioxide emissions on GDP is mostly studied as investigating the nexus within the framework of the Environmental Kuznets Curve (EKC) which was first studied in (Grossman and Krueger, 1992). In this regard model 2a and model 2b analyzes the nexus between per capita GDP and per capita carbon dioxide emissions. Table 4-4 presents the results of the estimation. It is clear that for OLS, Arellano-Bond one-step and two-step GMM and the Wald test results reject the null hypothesis stating that the coefficients of lagged per capita carbon dioxide emissions are jointly equal to zero at conventional significance level. In this regard it is logical to state that CO_2 emissions Granger-cause GDP with a negative relationship.

Figure 4-2 Environmental Kuznets Curve



Source: Adapted from Grossman & Krueger, 1992

The EKC curve as presented in Figure 4-2 depicts the idea propounded by Grossman and Krueger (1992) that pollutant concentration tend to increase at low level of incomes and consequently reaches to a turning point "once a country reaches this critical level of income its citizens begin to feel able to afford higher standards of environmental protection and so demands stricter regulations from their governments" (Grossman and Krueger, 1992: 3) Within this context the empirical results of model 2a does not supports the EKC hypothesis in a sense that, increasing CO_2 emissions would require per capita GDP to increase as well until it reaches the turning point however, the results of the analysis point to a negative causality relationship.

Table 4-5 Estimation Results for Model 2b

	CO_2 – GDP		
	(1)OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
GDP(-1)	0.457** (0. 215)	-0.279** (0.099)	-1.493** (0.437)
GDP(-2)	-0.033 (0.216)	-0.131 (0.104)	-1.498** (0.528)
CO_2(-1)	-0.191* (0.101)	0.708** (0.287)	3.051** (0.903)
CO_2(-2)	-0.075 (0.101)	0.197 (0.309)	3.288** (1.260)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.047	0.010	0.033
Sargan Test (ρ-level)	-	0.017	0.017
AB test (ρ-level)	-	0.565	0.514

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

To clarify the nexus between GDP and CO_2 emissions it is necessary to investigate the inverse relations as well thus model 2b is analyzed. Table 4-5 presents the estimation results for model 2b. It is clear that for conventional statistical significance levels the Wald test rejects the null hypothesis stating that the coefficients of lagged per capita GDP are jointly equal to zero thus it is safe to say that per capita GDP Granger-causes CO_2 emissions. The estimation results of Arellano-Bond one-step and two-step, except for OLS, indicate a positive relationship at the first lags of per capita GDP. The overall inference of the analysis would be that an increase in per capita GDP will proportionately lead to an increase in the CO_2 emissions. In this context the causality running in this direction supports the EKC hypothesis for the first period where environmental degradation increases with the increase in income level per capita.

Table 4-6 Estimation Results for Model 3a

	EC – CO_2		
	(1)OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
EC(-1)	0.238* (0.139)	0.219 (0.198)	-0.131 (0.516)
EC(-2)	-0.234* (0.142)	-0.230 (0.205)	0.041 (0.199)
CO_2(-1)	-0.259** (0.109)	-0.230 (0.166)	0.009 (0.395)
CO_2(-2)	0.078 (0.112)	0.082 (0.174)	-0.148 (0.184)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.053	0.378	0.489
Sargan Test (ρ-level)	-	0.421	0.431
AB test (ρ-level)	-	0.387	0.450

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

Considering the fact that the sample countries are still in the period of development and most of them are transition economies they may have yet to reach the level of income that is considered as a turning point which will carry them to the second phase of the EKC hypothesis where increases in GDP leads to improvement in the environment. An alternative analysis for the sample countries is that despite their level of economic growth a transition from fossil fuels that are intense in carbon dioxide emissions to renewable resources would both improve their GDP and the environment.

The final analysis is to check the nexus between energy consumption and carbon dioxide emissions. Considering the fact that the use of fossil fuels such as coal, petroleum and natural gas, generate high carbon dioxide emissions it would be logical to enunciate that there is a positive relationship between the two. In this sense increasing use of fossil fuels would lead to air pollution unless the fuels used are renewable resources, in that case even though energy consumption increases there would not be a per contra increase in carbon dioxide emissions.

Table 4-7 Estimation Results for Model 3b

	CO_2 – EC		
	(1)OLS	(2) Arellano-Bond one-step GMM	(3) Arellano-Bond two-step GMM
EC(-1)	-0.138 (0. 171)	-0.156 (0.207)	-0.800 (0.516)
EC(-2)	0.012 (0.177)	0.051 (0.219)	-0.154 (0.546)
CO_2(-1)	0.088 (0.219)	0.113 (0.289)	1.145 (0.816)
CO_2(-2)	-0.933 (0.223)	-0.156 (0.295)	0.054 (0.777)
Number of Obs.	117	117	117
Wald Test (ρ-level)	0.864	0.835	0.350
Sargan Test (ρ-level)	-	0.006	0.006
AB test (ρ-level)	-	0.217	0.148

GDP = per capita GDP in constant 2000 $ (in natural log), EC = per capita energy consumption (in natural log) Standard errors are in parenthesis. Estimates for constants are not presented. AB test is AR(2) in first differences
* Significance at the 10% level
** Significance at the 5% level
*** Significance at the 1% level

Model 3a that investigates the relationship between energy consumption and CO_2 is presented in table 4-6 and the inverse model 3b in table 4-7. For both models the results of Arellano-Bond one-step and two-step GMM does not present statistically significant outputs and the Wald test indicates that the null hypothesis is not rejected thus $H_0 : \sigma_l = 0$ and $H_0 : \xi_l = 0$. This result leads to an inference that there is no Granger causality relationship between CO_2 emissions and energy consumption at any conventional significance level. In one perspective this outcome denies the validity of a common belief that a change in energy consumption would have a proportionate change in the level of CO_2. Aside the fact that the results of the analysis do not provide evidence towards such relationship the visual inspection of the CO_2 emissions and energy consumption from the previous graphs presented in Figure 4-1 stand to differ.

There are several aspects to the absence of a causality between carbon dioxide emissions and energy consumption which will be addressed further in the conclusion however, basically the source of fuel profiles, total energy production and the environmental protection acts play significant role on the causality between the two.

CONCLUSION

The question this study analyzes, whether energy consumption and carbon dioxide emissions have a causality relationship with economic growth is answered for the sample countries of the EU member states of CEE namely; Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovak Republic, Slovenia, Hungary, Bulgaria, Romania and the three candidate countries; Turkey, Macedonia FYR and Croatia. The time period used in the study includes the years between 1997 and 2008 using the per capita values of GDP, energy consumption and CO_2 emissions and Arellano-Bond GMM model is implemented. The contribution of this study is that it brings a new approach to the literature on the relationship between energy consumption and economic growth by working with a dynamic panel data model, more specifically Arellano-Bond one-step and two-step GMM, which has not been used previously as aforementioned in Part Three. Furthermore, the countries and the time span also differ from the previously conducted studies.

Considering the fact that a consensus on the literature regarding this relationship has yet to be reached, this study provides another perspective on the issue. The results indicate evidence regarding a unidirectional causal relationship from energy consumption to economic growth; bidirectional causality between GDP and CO_2; no causal relationship between energy consumption and CO_2. Within this context this thesis supports the growth hypothesis however with a negative relationship. This implies that implementing efficient conservation policies would have a direct effect on economic growth however; policies that ignite the economic performance would not cause any divergence in the energy consumption.

Except for Turkey, Romania and Poland the sample countries are relatively small with an average population of nearly 14 million, their corresponding energy consumption is low as well but due to the use of fossil fuels they have high carbon dioxide emissions. There could be three logical explanations to why the causality between energy consumption and economic growth is unidirectional and one of them lies in the fact that all of these countries are dependent on imports in terms of energy.

Most of them obtain very low reserves while countries such as Estonia, Latvia, Slovenia and Macedonia possess nearly no reserves of oil, natural gas or coal and peat while others have very low reserves which urge them to import these fuel sources. Thereof as the import volume increases so as the burden on GDP ergo there is a unidirectional causality with a negative sign.

Second explanation could be the fact that the second lagged coefficient of the Arellano-Bond one-step GMM estimation in model 1a also has a statistically significant positive impact on per capita GDP. This leads to an overall inference that while the energy consumption of 2006 will have a positive effect on the per capita GDP of 2008, energy consumption of 2007 will have a negative impact. The reason for this may be due to the fact that energy consumption' effects on growth may not be short lived instead it takes two years for an increase in the energy consumption to cause growth. If the growth effect takes more than a year to be internalized by the economy than it is logical to observe negative causality in the first lag and positive causality in the second lag.

Third explanation is about the absent causality from economic growth to energy consumption however it is rather blunt. Logically as a country experiences economic growth with today's energy abundant production it is expected that there should be a corresponding increase in the energy consumption. Nevertheless the results indicate that during the time period, although the sample economies experience growth in both of the variables, they are not interrelated. Even though the individual country effects have been eliminated in the GMM model, there is still the countries' overall economic and energy profiles that should not be disregarded during the interpretation of the results. As aforementioned, the sample countries are developing and transition countries which are relatively small with low energy consumption. In this sense, as previously depicted in part two, planned economies were more and market economies less energy intensive therefore with the transition from planned to market economies, the countries maintain their economic growth however do not demand more energy. Consequently this brings about the possibility that these countries' energy consumption does not depend on their economic growth thereof the analysis does not indicate a causality running from economic growth to energy consumption.

The second analysis, model 2a, considered the causality relationship between economic growth and carbon dioxide emissions which consequently presented a bidirectional causal relationship. As table 4-4 indicates, there is negative causality from carbon dioxide emissions to per capita GDP for the first lag while a positive causality exists in the second lag. Within this context, the inference is somewhat similar to that of model 1a, such that the carbon dioxide emissions of 2006 have a positive effect while the carbon dioxide emissions of 2007 have a negative effect on 2008 per capita GDP. The results actually support the logical idea in two perspectives; one is that increasing carbon dioxide emissions would most probably be caused by an increase in energy consumption which indirectly leads to a decrease in per capita GDP which was proven by the results of the model 1a.

The second logical understanding concerns more of the environmental degradation and its indirect effects to the economy. As previously stated, the sample countries' abundant energy source is mainly generated from fossil fuels emitting high amounts of carbon dioxide thus an increase in energy consumption releases high amounts of carbon dioxide. The released carbon dioxide pollutes the air and deteriorates the ecological life, consequently harming the agricultural sector thus reducing growth. Human health is another aspect that is affected by the polluted air which increases both the private and public health care expenses and generates excess burden on the GDP.

For model 2a, the results of the Arellano-Bond one-step GMM presented in Table 4-5 indicate that, only for the first lag which is statistically significant, there is positive causality running from per capita GDP to carbon dioxide emissions. The first period of the EKC hypothesis indicate that until a country reaches to a level of development which is stated as the turning point, the environmental degradation accompanied by the per capita GDP increases jointly. Subsequent to a certain level of growth, the citizens demand for a healthier and more diversified environment, therefore the countries focus on environmental protection. In this regard, in the second period of the EKC hypothesis there is an inverse relationship between the per capita GDP and environmental degradation. The results of the model 2a support the EKC hypothesis for the first period. This result should be valid considering the fact that the sample countries within the corresponding time span are in the transition and developing period.

Although logically it is expected that there should be bidirectional or at least unidirectional causality between energy consumption and carbon dioxide emissions, the results of the analysis indicate no causality. Probably the absence of the causality is the most surprising finding of this study considering the fact that energy consumption is the main source of carbon dioxide emissions disregarding the generation of CO_2 directly in the natural biological cycle. The underlying reason for such an outcome could be based on two aspects which are energy source profiles of the countries and environmental protection policies.

Energy profiles matter in such a way that, in countries which have renewable or nuclear energy as abundant energy sources would most likely to have low levels of carbon dioxide emissions compared to those of which have fossil fuels. In this regard it is unlikely to observe any causal relationship between energy consumption and carbon dioxide emissions. Nevertheless, most of the sample countries use fossil fuels as primary energy sources therefore it is abrupt to observe no causality.

Another aspect might be the environmental protection policies such as the Kyoto Protocol. All of the sample countries are a party to the Kyoto Protocol thus are committed to reduce their carbon dioxide emissions to a specific level until 2012 except for Turkey whom despite being a party is not obligated with any commitment. These obligations lead countries to direct their attention on individual environmental protection policies, and towards more nuclear and renewable energy systems than conventional energy sources. Considering these aspects, the absence of a causal relationship could be more admissible.

In order to relate these analyses with the reality, it is necessary to point out the significance and the necessity of an economic examination. The main intuition is that energy, before the industrial revolution, was an aspect that was fuelling the production until after the industrial revolution and the intensive use of technology in production that it became the fourth factor in production along with, capital, labor and technological progress. With the introduction of energy as a production factor, the increasing dependence and its use, issues related to energy which are energy diversification, energy security, environmental protection, energy conservation and economic growth policies came into consideration. These issues have become vividly significant and in most ways costly to the world economy, especially to the vulnerable underdeveloped and developing countries.

Energy diversification in this context corresponds to the countries focusing on alternative means of sources and fuel types; meanwhile energy security corresponds to securing the supply and compensating the market demand. Although they have individual significance, these topics are interrelated such that energy diversification is required in order to maintain the energy security. Considering the fact that fossil fuel reserves are expected to gradually diminish in time, diverging to renewable and nuclear energy will consequently secure the energy supply, diversify energy sources and help improve the environment through decreasing the carbon dioxide emissions. All these matters subsequently lead countries to define the adequate energy conservation and economic growth policies.

Within this framework, these energy related issues are of significance to the sample countries owing to the fact that, although they have other energy sources, their primary energy sources are oil and natural gas which are necessary to be diversified for securing the energy supply. Aside from the supply security, one other aspect of the energy security is that these countries' primary energy resources are dependent on foreign reserves which could lead to an energy crisis in the occurrence of a political conflict between the dependent country and the exporter.

Another aspect is the environmental protection and preserving the biological diversity. Although economic growth and maintaining the level of development is necessary, today it is realized that the order and balance in the natural life cycle is as much vital and vulnerable as the economy. In many cases, disregarding the nuclear meltdowns and oil tanker disasters, the drawbacks and the problems caused by a disruption on the environment is not as rapidly observed as it would be in the economy. Today the air pollution and the global warming issues are the drawbacks of partly the green house gas emissions of today but probably mostly due to the accumulated carbon dioxide through the industrial revolution years until today, in which time span the abundant source of energy was fossil fuels. With the intense use of fossil fuels, today a vital environmental degradation might not be observed however if not converted to carbon free energy, in the future it is most likely to be observed.

In this regard, probably the most adequate and efficient energy policy for the sample countries in order to secure their energy supply, diversify their energy profile and meet with the commitments regarding the reduction of carbon dioxide emissions, they might consider generating domestic energy via renewable energy systems and nuclear power plants. Besides, the results of the analyses support such a policy suggestion in the sense that; (1) producing domestic energy would decrease the dependence on foreign reserves, which would lower imports therefore increasing GDP, (2) converting to low carbon emitting fuels will reduce the carbon dioxide emissions help the countries meet their commitments under Kyoto Protocol, (3) through the usage of a variety of energy systems such as solar, wind, ocean, geothermal, biomass, hydropower and nuclear energy the countries will be able to diversify their energy supply therefore secure it as well, (4) if the all above holds, then model 3a and model 3b of this study will make sense and support no causality between energy consumption and carbon dioxide emissions.

The findings of this study should be tentative and considered as a new perspective in the literature regarding the nexus between economic growth, energy consumption and carbon dioxide emissions. The study could be reexamined with a better data however, data before 1990 regarding the sample countries is not available on the individual basis rather it is found as bloc countries as a whole as they are transition economies. Therefore the study is limited to analyze the data after 1990. Furthermore, as an air pollutant and an aspect of environmental degradation, this study used only the data of CO_2 however the results may vary with an overall data of all the green house gasses. Further analysis could be conducted by enlarging the cross sections however keeping the instrumental variables low in order for the over-identified restriction to be valid.

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