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MASTER’S THESIS

THE EFFECTS OF ENERGY PRODUCED FROM RENEWABLE SOURCES ON CARBON DIOXIDE EMISSIONS: AN EMPIRICAL ANALYSIS OF EUROPEAN UNION MEMBER COUNTRIES

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INTRODUCTION

Energy is one of the priorities in the world nowadays. Therefore, a lot is being done to improve the ways in which it is being produced and there are many possible solutions for this global issue. Environmental degradation together with different economic and social problems has led many countries to start producing energy using sources such as wind, sunlight, water, waves, geothermal and other. Renewable energy sources are unlimited, and they replenish naturally. Taking into account future and current social and economic needs, renewable energy production is considered as a clean source of energy. According to Panwar, Kaushik and Kothari (2011) the use of these resources produces a low amount of secondary wastes and minimizes environmental impacts. Non-renewable energy sources still stand for the traditional and non-excludable way for the production of energy, but governments actively try to increase the share of clean production of energy and to replace the existing power plants that are largely contributing to the emissions of CO_2 into the atmosphere.

The assumptions are that the current methods of creating energy are about to change radically in the future. The reason for that is a low supply of natural gas and oil and more significantly, changes in climate. The climate changes are the result of the release of gases during the combustion of fuels. Non-renewable energy sources like fossil fuels were formed a long time ago in history from animal and plant remaining. Intensive use of fossil fuels, especially during the 20th century caused that coal reserves will be enough for the next 80 years and oil reserves for the next 50 years approximately.

Fossil fuels are the main resources to produce electricity today. Unfortunately, fossil fuels are the major polluters of the environment. The burning of fossil fuels releases significant amounts of CO_2, which is one of the gases that contribute to the change of climate, the creation of the so-called greenhouse effect and global warming. Carbon dioxide is considered as the most responsible and stands for about 57% of global warming according to Moriarty and Honnery (2012).

The average temperature on the surface of the earth has increased over time due to rising concentrations of greenhouse gases, including mostly carbon dioxide and also, nitrous oxide, methane, and sulfur oxide. Precipitation patterns, storm severity, and the increase in overall sea level are just some of the climate change occurrences that have emerged lately states Muis, Hashim, Manan, Taha and Douglas (2010). Moriarty and Honnery (2011) also state that methods for reducing GHG include using renewable energy sources and higher energy efficiency to cut CO_2 emissions from energy production.

The strategy of the European Union regarding renewable energy sources is on a path for a greener and low carbon economy. The goals have been set and determined for renewables, and they include reaching a share of 20% of all the energy consumed by the year 2020.

These directives are obligatory for all the members of the union. The orientation towards renewable energy in Europe started in the year 1997. It continued to grow from its initial goals to de-carbonize the energy sector and address the problems of using fossil fuels to an industry that employs over 1.5 million workers today, with an expected increase to 3 million by the year 2020. However, this young and developing industry is still facing many difficulties and barriers, which are yet to be met and resolved. Nevertheless, the success of the production, promotion, and usage of this kind mean that renewable energy should not be ignored. European directives and legislative have the main goal of creating an energy market that is sustainable, competitive and secure. Developed countries produce the highest levels of emission, and must bear the highest responsibility for global warming. Nevertheless, action must also be taken by developing countries to evade increases in emission levels in the future while their population grows and economies develop (Omer, 2008).

The purpose of this thesis is to analyze the relationship between production of electricity gained from renewable energy sources and CO_2 emissions. Furthermore, the purpose is to show the significance of renewables in the global production of energy and give emphasis to the environmental degradation caused by the CO_2 emissions.

This thesis attempts to answer the following research question:

- Do increases in the renewable energy production help reduce CO2 emissions in the European Union countries?

The hypothesis is set as follows:

- There is a significant and negative effect of the use of energy gained from renewable sources on CO_2 emissions reduction in the European Union countries.

The main objectives (goals) of this master's thesis are as follows:

- to explain the appropriate theoretical/conceptual framework used to explore the relationship between renewable energy sources and CO_2 emissions;
- to identify and analyze specific environmental issues that arise due to CO_2 emissions;
- to explain the negative effects of CO_2 emissions on the environment;
- to determine level up to which countries are fulfilling their promises and obligations regarding the consumption of renewable energy sources and decrease of carbon dioxide emissions;
- to analyze the relationship of energy produced from renewable energy sources on CO_2 emission decrease;

- to give a recommendations for further actions regarding the consumption of energy from renewable sources and reduction of CO_2 emissions based on the results of the research.

This master thesis has 6 chapters. In Chapter 1, description of renewable energy sources and all the primary sources of energy production are explained in detail and they include the following: solar, hydropower, wind, geothermal and biomass. In addition, positive and negative effects of renewable energy sources, as well as the promotion strategies are listed and described in details. Throughout Chapter 2, more attention is given to the CO_2 emissions that represent the most important cause of the environmental degradation and the sources of these emissions. In Chapter 3, the focus is on the link between environmental protection and economic growth, explained using the Kuznets curve hypothesis and sustainable development principle. All the major challenges of reducing the CO_2 emissions are also covered in this chapter. Chapter 4 applies all the learning from previous chapters to the EU strategy towards sustainable energy and Kyoto Protocol. Progress of each European Union member state towards their 2020 targets is carefully examined and compared. Chapter 5 includes all the elements of empirical analysis, explained in detail, which attempts to show the impact of renewable energy on carbon dioxide emissions. The results of empirical analysis are presented in the chapter 6.

1 DESCRIPTION OF RENEWABLE ENERGY SOURCES

1.1 The primary sources and forms of renewable energy

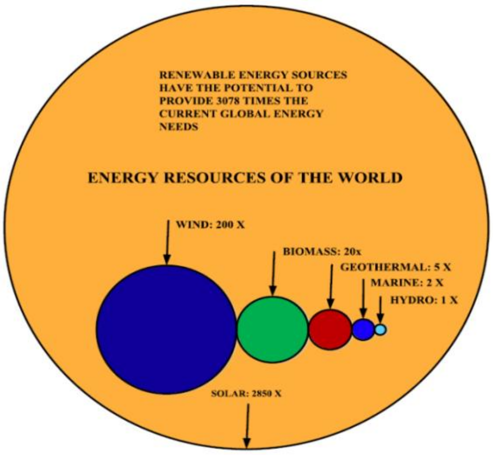
1.1.1 Difference between renewable and non-renewable energy sources

Most important clean and endless energy resources include the wind, solar, hydro, biomass, geothermal and marine energy. According to Ćulahović (2008), the growth of natural resources is a function of two variables. These variables are existing stock of resources and carrying capacity of the environment, which is the maximum amount of resources that exists in nature that man has never spent. If the stock of resources is equal to the carrier capacity of the environment, growth will be zero because there is no space for additional growth. If a certain level of inventory of resources is near the carrying capacity of the environment, lower inventory levels will lead to higher growth. However, if the supply of resources is too low, then the rate of growth of stocks will depend on the amount of stock. For example, in fish or animal, if only a small number of species remains due to overfishing or excessive hunting, this would reduce their reproductive capacity and will not lead to the regeneration of stocks.

Renewable energy sources include wind power, solar power, hydroelectric energy power, tidal power, geothermal energy, and biomass. These energy sources are considered as key alternatives to fossil fuels. Using renewable energy sources entails a reduction in greenhouse gas emissions, ensuring energy supply caused by the diversity of use of those resources. Using these sources leads to a reduction in dependence on the EU regarding unreliable and non-existent markets of fossil fuels, primarily oil and gas.

Absence of non-renewable energy should initiate actions for active market findings of alternative sources such as the ones from renewable sources. Benefits of the same are reflected in the long-term economic sustainability thorough of the environmental benefits. However, renewable energy is still not sufficiently efficient to fully meet the energy demand, and it is necessary to work on bridging this gap. Energy gained from renewable sources has significantly smaller energy value compared to fossil fuels. They are also geographically more widely distributed and connected mainly to the distribution network. On the one hand, there are engineers motivated by empirical knowledge about the complexity of the electric power system that expresses concerns regarding the fundamental feasibility of mass introduction of the unregulated and unmanaged generator in the electricity. On the other hand, there are enthusiastic advocates of renewable energy sources like wind power and cogeneration of electricity and heat, who believe that such production units must be introduced into operation to meet domestic and international demands for a reduction of CO_2 emissions. Ellabban, Abu-Rub and Blaabjerg (2014) say that renewable energy sources have an ability to produce 3000 times the current world demand for energy. It is very important to deploy renewable energy sources in the most optimal way in order to minimize the costs and maximize generation. Iqbal, Azam, Naeem, Khwaja and Anpalagan (2014) showed that there is a constant increase in research activity when it comes to methods for optimization of production of renewable energy sources. It is expected that in the future this research is going to concentrate on sources such as geothermal, hydro, biofuel, biomass and grid connected renewable energy sources. Based on the research done by Varun, Prakash, and Bhat (2009) it has been concluded that small hydro and wind power plants are the most sustainable sources for the production of electricity.

Figure 1. Energy resources of the world



Source: O. Ellabban, H. Abu-Rub, and F. Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, 2014, p. 2.

Moreover, renewable sources increase the sustainability of the electricity system in case of a possible energy crisis in power generation, which is now dependent on the delivery of coal, gas, and oil. Plant and animal remaining formed non-renewable energy sources like fossil fuels a few hundred million years ago. Fossil fuels are the main resources for producing electricity today. Unfortunately, there is no possibility of recovery of fossil fuels, which are also the major polluters of the environment. The burning of fossil fuels releases substantial amounts of CO_2, which is one of the gases that contribute to climate change. Serious economic problems and problems that have occurred due to changes in climate have led many countries to start using alternative energy sources: solar, wind, waves, geothermal energy and other. Moving to energy systems based on renewables seems to have a bright future as the costs of such type of energy production have been declining rapidly in the past 30 years. In contrast to solar and wind costs dropping substantially, prices of gas and oil are still fluctuating (Akella, Saini, and Sharma, 2009). Table 1 shows different usage of the main renewable sources.

Table 1. Main renewable energy sources and their usage form

Energy source	**Energy conversion and usage options**
Hydropower	Power generation
Modern biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home system, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pumps
Wave	Numerous designs

Source: N. Panwar, S. Kaushik, and S. Kothari, Role of renewable energy sources in environmental protection: A review, 2011, p. 2.

Table 2. Global renewable energy scenario by 2040

Renewable energy sources consumption	**2001**	**2010**	**2020**	**2030**	**2040**
Total consumption (million tons oil equivalent)	10,038	10,549	11,425	12,352	13,310
Biomass	1,080	1,313	1,791	2,483	3,271
Large hydro	22.7	266	309	341	358
Geothermal	43.2	86	186	333	493
Small hydro	9.5	19	49	106	189

(Table continues)

(Continued)

Renewable energy sources consumption	2001	2010	2020	2030	2040
Wind	4.7	44	266	542	688
Solar thermal	4.1	15	66	244	480
Photovoltaic	0.1	2	24	221	784
Solar thermal electricity	0.1	0.4	3	16	68
Marine (tidal/wave/ocean)	0.05	0.1	0.4	3	20
Total RES	1,365.5	1,745.5	2,964.4	4,289	6,351
Renewable energy source contribution (%)	13.6	16.6	23.6	34.7	47.7

Source: N. Panwar, S. Kaushik, and S. Kothari, Role of renewable energy sources in environmental protection: A review, 2011, p. 2.

According to Panwar et al. (2011), the share of renewables is projected to increase between 30% and 80% by the year 2010, which is a very significant change compared to today's level. The global renewables development by 2040 is presented in Table 2. We can notice from this table how renewable energy source contribution is expected to rise from 13.6% in year 2001 to 47.7% in year 2040. Also, some types of production like wind or photovoltaic will have very significant increase while the others will also increase but more slowly.

1.1.2 Solar energy

Solar energy is the primary driver of climate and life cycles on Earth and source of all powers says Panwar et al. (2011). Today, the sun is perceived as a source of pleasure and has an enormous untapped potential for meeting the energy needs with minimal impact on global warming. The sun is also used for heating by using solar radiation. This way of heating involves the direct application of heating facilities, water heating, or more recently use in refrigeration systems. Heat application is divided into passive and active. The oldest form of solar energy use is in the passive architecture. Passive construction means constructing housing units and buildings so that they are more heated during colder part of the year and less during the warmer season. This method can be achieved thanks to the fact that the angle (declination) under which the sun, in the regions north of the equator, is greater in summer than in winter. For example, the passive solution is a shelter in the southern part of the house. Passive construction can further be in the proper insulation of the building; walls and floors with an additional ground for heat accumulation (accumulation during the day for the night use), adequate performance windows and another light source from specific channels. Controlled ventilation also contributes to efficiency and comfort. Planned landscaping around the building is designed to create shadows for summer and providing shelter from the wind in winter. The usage of solar energy through thermal collectors is a bit more complicated than passive solutions, but certainly the most economical. Solutions may or may not include active components and can use water or air as the working fluid. These solutions are used for heating swimming pools or industrial facilities.

Electricity is produced from solar energy in two different ways: indirectly through heat cycle process and directly using the photoelectric effect. The first approach is currently more efficient, but there is a greater incentive for the second method, and it is developing faster. When it comes to the conversion of thermal energy into electricity, thermal power plants which use solar energy do not differ fundamentally from other power plants. They always apply a process over a turbine or other heat engine which then transforms heat energy into electrical and mechanical energy in the end. There are three different solutions to solar thermal power plants relevant to the experience and the potential for practical application: parabolic flow, solar tower, and parabolic dish. All of these power plants primarily use direct sunlight, and for efficiency they must follow the movement of the sun. Besides the above-mentioned solutions, it is interesting to mention so-called solar chimney, which is based on solar collectors and air turbine generators. These are temporary and experimental solutions, but for now their potential seems smaller than the potential of solar thermal power plants.

Photovoltaic use of solar energy with its exponential growth of 40% a year is currently the fastest growing new source of renewables generation. The appearance and development of new technologies such as thin-film on the market, with excellent efficiency, represent the hope that the needs for primary raw materials (ex. silicon and indium) can be less stressful. The photoelectric effect is a process that can produce electrical energy, and it is created when a photon of sufficient energy hits an electron in a neutral semiconductor junction. Besides the fact that it is the basis of most other energy sources, solar energy offers the greatest variety of its uses, starting from the first and most common mere passive construction and solar collectors for heating. It is followed by solar thermal power plants with the experience and level of development, which is now, close to cost for conventional sources. Finally, there are photovoltaic cells with the ability to directly produce electricity. The exponential increase in the production and development of photovoltaic cells increased the involvement of the environmental protection in the electricity price, and the development of the electricity market is the basis for a long-term brighter perspective of solar energy usage. Of course, when using solar energy, economic activity and all indirect benefits (employment, lower energy imports) should be taken into consideration. Biggest advantages of this type of electricity production are that it has no emissions of greenhouse gases and has direct conversion of energy. Few factors that are not in favor of solar power generation are small power of facilities, large space requirements per unit of power, possible adverse effects due to the reflection of light, and dependence on weather conditions. Even though there is a relatively rapid decline in investments for systems with photovoltaic cells, significant capital costs per one unit of power are also a problem. This type of energy production has its future, but there are still many aspects yet to be improved, starting from the price of production and making this technology a better investment.

1.1.3 Hydropower

Probably the most important renewable energy source is hydro. Hydropower produces no pollution of water, soil and atmosphere, however, there is an influence on the ecosystem of rivers and their environment. Production costs are relatively small, but, on the other hand, high investment costs are required. High operational reliability represents a security for investors if they manage to build it in the first place because there are significant dependence on climate (hydrological) conditions. There are many explanations how electrical energy is produced from water. According to Amponsah, Troldborg, Kington, Aalders and Hough (2014), in hydropower production power generation uses the kinetic energy produced by rushing water. The water powers a turbine into hydroelectric generating stations. The turbine then converts the water's movement into mechanical and electrical energy. There are many different types of hydropower plants. The power of the plants varies in a huge range of scales, from a few watts to several GW for large hydropower plants. The greatest projects include Itaipu in Brazil with 14,000 MW and Three Gorges in China with 22,400 MW. According to Ellabban, Abu-Rub and Blaabjerg (2014), both of these produce between 80 to 100 TWh/yr.

Hydropower plants are very specific since they are unique projects. They are very much influenced by the geographical conditions and the river on which the facility is being built. This characteristic directly affects the construction prices, and it can vary very much. According to the type of water-flow and operation hydropower plants are categorized into three categories.

The first type is run of river, which gains energy from the natural flow of the river. Generation of the energy very much depends on the terrain and the natural river condition. Therefore, this type of plant is subject to seasonal variations since it depends mainly on the rainfalls. Some small accumulation may be possible. The second type of hydropower plants is storage (reservoir) because they are designed to accumulate water for later use. This process reduces the need and dependence on the inflow of water. The plant with turbine and generator is connected with pipes to the reservoir. Finally, there are pumped storage hydropower plants, which are not energy sources but rather storage devices. With regards to their scale, this type differs from small to large, subject to the topography and hydrology. Hydropower plants are proven and technology with a long history. Furthermore, this way of producing energy is one of the most efficient regarding the conversion of energy due to direct transformation of kinetic energy into electricity according to Ellabban, Abu-Rub and Blaabjerg, (2014).

Hydropower is one of the primary sources of electric energy, and its growth is still anticipated in the future. Although the creation of large dams became risky for investment, their importance is still substantial, particularly regarding the construction of small dams, for which there is an interest in considering the existence of a lot of unused potential worldwide. Therefore, the growth of the same remains inevitable, but at a slower trajectory, which means that its share in the portfolio of primary energy sources will indeed reduce in the future. There is a need for improvements and performance measures that are necessary for dams if there is still a continued support to hydropower as a form of clean, renewable energy source says Herzog, Lipman, and Kammen (2001).

1.1.4 Wind energy

The wind has served as a basis of mechanical energy for centuries so far. In recent years, it is increasingly becoming an economically attractive source of electricity. Today there is an extensive use of small and medium sized wind power plants up to one MW. Input power for wind turbines can be achieved by converting the force of the wind into rotational energy. The quantity of energy that the wind transmits to the propeller depends on the surface of the circle that makes the rotor spin, as well as wind speed and air density. This process means that it is impossible to use all the energy from the wind.

One of the biggest problems with grid connection is that the wind in the available transmission network is significantly smaller than the wind that is more than 30 km away from the network. Limitations in the power transmission lines may require the construction of long lines that increase costs. When working on a network, there is also the problem of excessive wind - rejection of wind power when the total load in the system exceeds the production of primary power plants. The most significant limitation is the high variability of the wind, which can be reduced by installing a wind energy plants over a wide area. Low predictability of wind is a problem that can be reduced by using improved methods of forecasting. It is possible to control better the use of wind power by controlling the inclination of blades and variable speed.

However, in conclusion, wind power can reduce fuel consumption by thermal power plants, but cannot reduce their construction because they cannot guarantee the production of electricity in critical periods due to problems with frequency, interference, and instability. The main drawback is due to high variability of geographical location, the shape of the land and regular period. The advantages of this technology, which is still developing, are low running costs, no emissions into the atmosphere and no wastewater. The impact of wind power plants on the environment can be seen through the effects of the construction phase (preparation of the field), distortion of landscape appearance (use of land) and impact during operation (noise, electromagnetic interference, impact on birds).

1.1.5 Geothermal energy

Geothermal energy is an almost inexhaustible source of energy, which has relatively low production costs and produces insignificant emissions into the environment. Classification of geothermal energy in renewables is justified in the broader meaning. The energy inside the earth is not renewable, but there is so much of it that the eventual exhaustion is not possible. Using data obtained by drilling, satellite imaging, and modeling, it is feasible to estimate the geothermal sources. In doing so, the most critical data include temperatures, the amount of water/steam and the configuration of the soil in a given area. Geothermal resources can be classified according to the temperature: low temperature (below 90° C), high temperature (over 150° C), and the mean temperature between. Temperature determines the possibilities of use and routes of administration. Only high-temperature sources are considered cost-effective and practical to produce electricity.

Resource assessment is usually done for production of electricity and heat energy direct use. The simplest and most promising way of exploiting geothermal energy is a direct use of thermal energy for various purposes in tourism, agriculture, industry and local heating. Direct application can be single or combined. The combinations can be with other (conventional) methods of production of thermal energy or electrical energy generation from geothermal sources.

Direct application is the more applicable for heating and immediately followed by tubs, greenhouses, aquaculture and industry. Each country has its peculiarities depending not only on the geothermal resources but also on many other factors. Electricity generation using the geothermal source in principle is similar to the classical conversion inside the caloric energy from conventional sources of heat (e.g. coal). The similarity stops when it comes to the fact that it is required to reveal the geothermal digging site and that a borehole of several miles (or more of them) has to be made. Also, parameters of the geothermal sources are very rarely similar with the context of the traditional thermal power plants. Having taken everything into consideration, it looks like geothermal energy is a renewable source that does not have problems with inconsistency. The limitation is that it can be used only when there is a finding. This is a significant problem for direct use and potentially an issue for sites that are not near the electrical network.

1.1.6 Biomass energy

Biomass technology, which is still in the development stage, falls into the category of renewables. Biomass is the recyclable portion of waste, residues, and products of agricultural production (plant and animal), forestry and related industries. Biomass energy comes in solid, liquid (biodiesel, bio-ethanol, bio-methanol) and gaseous state (biogas, gas from biomass gasification and landfill gas). Biomass is a renewable source of energy and is divided into non-wood, wood and animal waste. Within these types certain subsets can be distinguished like wooden biomass (made from forest residues and waste wood), timber-grown biomass (made from trees that are growing fast), non-wood grown biomass (algae and grasses), agriculture residues and waste, animal waste and scrap, urban and industrial waste.

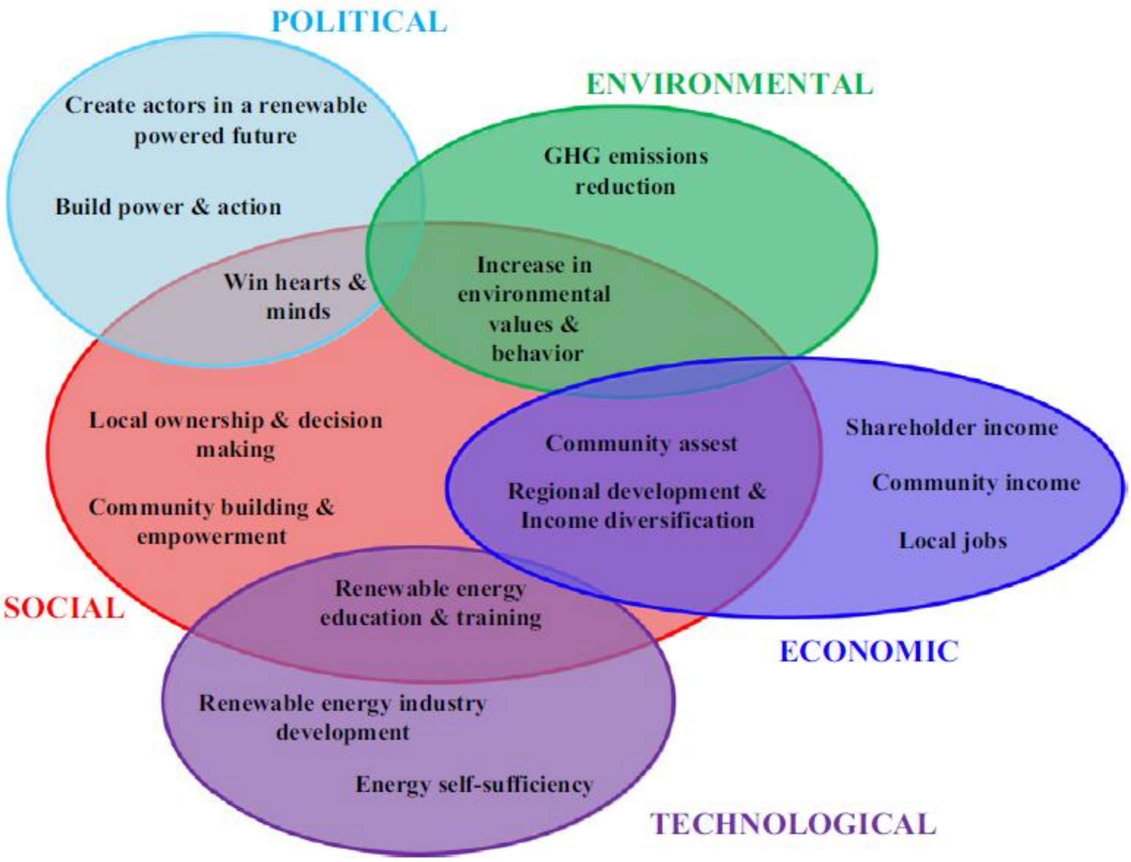
The main advantage of using biomass as energy source are abundant resources, not only in the case of planted crop plants but also when it comes to waste materials in agriculture and food industry. Gases generated using biomass can also be used in energy production. Biomass can be directly converted into energy simply by burning (combustion). Thus it produces superheated steam for heating in industrial facilities and households or for generating electricity in small thermal power plants. The advantages of biomass compared to fossil fuels are much less emissions and waste products. It is estimated that the burden of the atmosphere with CO_2 using biomass as fuel is negligible since the amount of CO_2 emitted during burning is the same as the amount of absorbed CO_2 during growth of plants. Therefore, regarding the CO_2 emissions, it is considered neutral, since the quantity of CO_2 emitted in combustion is compensated with the amount of CO_2 absorbed by the breeding biomass in the process of photosynthesis. Vast areas for restoration of biomass consumed are required, and the methods of collecting, transporting and processing of biomass are producing emissions that go into the environment. However, biomass creates other polluting gases and wastewater. Only in large facilities construction of waste recycling is cost-effective, while in the smaller facilities it is not. Therefore, the question is how profitable it is in ecological terms. Also, the collection, transport, and storage of biomass are very costly, which is another drawback of this technology.

Using biomass also has an impact on employment, like the creation of new and retention of existing jobs. Furthermore, it is increasing local and regional economic activity, earning an extra income in agriculture, forestry and wood industry through the sale of biomass fuel.

1.2 Positive and negative environmental effects of renewable energy sources

Energy from renewable sources brings a lot of benefits, both in the political, environmental, economic, as well as in social and technological sense. These advantages are illustrated in Figure 2. Before we address adverse effects, it is necessary to look back at the advantages and disadvantages of these resources, which are given in Table 3. Production of energy from renewable sources is considered very positive in general and most of the advantages are linked to the unlimited supply and environmental friendliness. On the other hand, almost all types of production have similar disadvantages in common and they include low efficiency of production and high costs.

Figure 2. Global benefits of renewable energies production



Source: O. Ellabban, H. Abu-Rub, and F. Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, 2014, p. 12.

Table 3. Advantages and disadvantages of different renewable energy resources

Energy source	**Advantages**	**Disadvantages**
Hydropower	- Plentiful, safe and clean - Simply stored in reservoirs - Relatively inexpensive way for electricity production - Offers recreational benefits like boating, fishing, etc.	- Possible flooding of surrounding communities and landscapes - Dams have major ecological impacts on local hydrology, can have a significant environmental impact - Can be used only where there is a water supply - Best sites for dams have already been developed
Solar	- Potentially infinite energy supply - Causes no air or water pollution	- May not be cost effective - Storage and backup are necessary - Reliability depends on availability of sunlight

(Table continues)

(Continued)

Energy source	Advantages	Disadvantages
Wind	- A free source of energy - Produces no water or air pollution - Wind farms are relatively inexpensive to build - Land around wind farms can have other uses	- Requires constant and significant amounts of wind - Wind farms require significant amounts of land - Can have a significant visual impact on landscapes - Need better ways to store energy
Biomass	- Abundant and renewable - Can be used to burn waste products	- Burning biomass can result in air pollution - May not be cost effective
Marine energy	- Ideal for an island country - Captures energy that would otherwise not be collected	- Construction can be costly - Opposed by some environmental groups as having a negative impact on wildlife - Takes up lots of space and difficult for shipping to move around
Geothermal	- Provides an unlimited supply of energy - Produces no air or water pollution	- Start-up/development costs can be expensive - Due to corrosion maintenance costs can be a problem

Source: O. Ellabban, H. Abu-Rub, and F. Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, 2014, p. 11.

Regarding photovoltaic systems, their positive effects on the environment are much more significant in terms of their adverse effects. The production of electricity by mentioned systems does not produce CO_2 emissions or any other emissions of particles that cause respiratory problem to humans and animals. Furthermore, it also does not produce noise and heavy metal emissions. Solar thermal power plants have a significant influence on the land and the environment because of their massiveness and occupation of a large area. The same substantially reduce CO_2 emissions. On the other hand, if we consider the solar thermal system, there is no need for fuels and combustion for those systems, which makes them very user-friendly to the environment. For the production of biofuels edible oils are used, thus producing them reduces the GHG emissions depending on the concentration of biofuels in traditional fuels. During its operation, fuel cells do not produce emissions and particles, making them environmentally very friendly. During the simultaneous production of electricity and heat these cells are minimizing the waste heat, which prevents impact on eco-habitats in water that is used for cooling. Since the near shore bottom mounted devices and offshore floating devices are calming the sea, wave energy has its positive impact regarding the protection of the coast from waves. According to Vezmar et al. (2014), plants for tidal energy do not have emissions and contribution to acid rains.

Even though production of renewable energy is considered as a clean and efficient method, certain adverse effects on the environment occur in this process. Potential adverse effects of the renewable energy sources on the environment are described in Table 4 for each of the main types. Most types of renewable energy production have same negative effect in common and it includes changes in landscape and soil erosion. Also, killing fish and birds is a big problem with wind and marine energy production.

Table 4. Potential negative effects of the renewable energy sources on the environment

Type of renewable sources of energy	**Potential negative effect on environment**
Hydropower	- Local ecosystems may be affected by the construction of the plant - Social and cultural problems with local communities
Solar	- Changes in landscape and soil erosion - Hazardous wastes
Wind	- Changes in landscape and soil erosion - Noise production - Killing birds with the blades
Biomass	- Can produce CO_2 emissions during the burning process - Changes in landscape and soil erosion - Hazardous wastes
Marine energy	- Changes in landscape - Drop in water motion and circulation - Killing fish with blades and changes of sea ecosystem
Geothermal	- Polluting waterways - Possible air pollution - Changes in landscape

Source: O. Ellabban, H. Abu-Rub, and F. Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, 2014, p. 11.

Energy produced from renewables, in addition to their benefits can have significant negative environmental impacts. In terms of hydropower, the dams can influence the migration of organisms, affect the temperature of the water and the accumulation of buildup downstream in the rivers. Also, short-term peaks in water flow that occur during operation of hydropower plants can have a negative impact on fish and their habitats.

Even solar energy production can have some negative environmental consequences. Among various things, solar cells (photovoltaic) affect the natural ecosystem in various ways. Their modules may contain certain toxic substances, where there is a possible risk of releases of mentioned chemicals into the environment in case of fire. It is important to mention the threat of solar cells batteries to natural resources because the lifetime of these batteries is short and they contain heavy metals such as cadmium. There can also occur some emissions during production and transportation of solar cells, which can have an impact on air pollution (Mahajan, 2012).

Regarding the wind energy resources, it is stated that wind turbines kill bats and birds, destroy ecosystems, and distract wild animals as well. Negative impact on the environment can occur during construction and operation of wind turbines, mostly on birds and whales, landscape, sustainable use of land (including protected areas), as well as the marine environment.

The negative impact of biomass on the environment can be reflected in the form of depletion of land and agro-biodiversity. In this case, it is necessary to mention the loss, stress, and waste of water, as well as poor management and pollution of water resources, which has an adverse impact on land and vegetation. Biomass potential can be taken from unsustainable forest sources. There are also negative impacts on forest management and cultivation of biomass crops on ecosystems and habitats. There are also the implications associated with emissions in the transport of biomass, implications on air quality depending on the type of biomass used, as well as a high level of water consumption for biomass cropping leading to a problem in areas where access to water is limited (Kudoh et al., 2011).

Even though promotion of renewable energy sources is a great thing, there are certain dilemmas regarding the adverse effects that might occur. Many jobs could be lost due to renewable energy development. People that worked on non-renewable energy sources production will lose their jobs. Private consumers of energy will have to pay more to get less energy since the price of electricity will be bigger. Purchasing power will decline. The goal should be making jobs but at the same time having least disadvantages possible, like enormous costs of energy. Some of the reports are stating that the idea of renewable energy promotion was indeed positive in the beginning, but the promotion of energies like solar photovoltaic PV and wind power are negative in the end.

1.3 Promotion strategies of renewable energy sources

Demands for energy in the world increase dramatically nowadays. Also, the increases in the price of oil and gas have given more emphasis to renewable energies in the European Union. Governments heavily debate about the feed-in prices for power production. In recent years due to significant public incentives in the form of feed-in-tariffs, in many European countries, the development of this sector has gradually increased. Unfortunately, usage of these energy sources' competitive costs is not possible today, but still, there are ways to promote and foster these ways of producing energy. This is one of the most important issues of the European Union member states. Appropriate support must be provided to achieve defined long-term objectives of energy policy. If non-renewable resources run out, and they eventually will, the incentive to increase renewable energies share will rise, since renewable will be cheaper says Reiche and Bechberger (2004). The untapped potential of biomass, solar, hydropower, wind power and geothermal energy is still high.

Different promotion strategies are used to motivate investors to invest in renewable energies. Without the help from the government, the share of clean energy would be much lower since this type of technology is still young and expensive and investing in renewable energies is risky and not profitable. The European Union member countries have an agreement to reduce emissions of CO_2 by 20% until 2020 compared to the level in 1990. Reaching these goals might be hard for some countries, and therefore, it is of crucial importance to apply adequate promotion strategies. Support for a broad range of renewable resources is needed. At the beginning, countries have favored one or two different sources of energy mainly due to their geographic condition. For example, countries with higher mountains and with much water supplies have favored hydropower plants, like Austria and other Alpine countries.

On the other hand, countries such as Germany and Scandinavian countries based their renewable resources production on wind energy. Natural conditions and geography are a critical parameter for renewable energy sources development. Some European countries such as the United Kingdom and the Netherlands have access to oil and gas inside their borders, and this availability of non-renewable resources can be another issue. Furthermore, solar energy production is more popular and utilized in southern parts of Europe like Greece, since the climate is more suitable than in northern areas of Sweden.

As already mentioned, producing sustainable energy from renewable sources is not cost efficient and has cost disadvantage compared to the fuels like gas, nuclear power or coal. The logical question is how to motivate countries to produce energy, which does not make enough profit. All the states have set up various schemes to support this development, says Ringel (2006).

Most popular policies among the countries in the European Union are feed-in tariffs. Feed-in tariffs are the prices of renewable electricity determined by governments that provide producers with a reasonable margin of profit and, on the other hand, quota obligations which are fixed amounts of green electricity generated proposed by the government. It can be seen that different member states of the European Union have different results in implementing promotion strategies for renewable resources.

Reiche and Bechberger (2004) state that not all the countries have the same definition of renewable resources production. For example, some countries give subsidies for large hydro plants also. The European Union directives regularly force countries to increase the share of renewable energy and give them reference values for their success. This is quite a challenge even for the pioneers and countries with much experience in this field.

2 CO_2 EMISSIONS IN THE EUROPEAN UNION COUNTRIES

2.1 CO_2 Emissions trends in the European Union countries

Large amounts of greenhouse gases are associated with the occurrence of climate changes. These gases among all include carbon dioxide (CO_2). The greenhouse effect is vital for the existence of life on Earth, and when the same is uncontrolled, there is an uninterrupted increase of the planet's average temperature. The increase in temperature leads to undesirable consequences for the environment and the survival of the planet. Due to the global warming CO_2 is considered as the main factor responsible for such climate changes says Marques, Fuinhas and Pires Manso, (2010).

Most of the European Union member countries experience energy-led growth and consume a lot of energy. Non-renewable and conventional sources of energy like coal, gas or oil are used for large part of this energy production. Environmental damage is considered to be caused by an increase in CO_2 emissions, which is the primary source of greenhouse gases effect, says Shafiei and Salim (2014). They also emphasize the growing problem of environmental degradation that is causing concerns worldwide and all sorts of political, social and economic pressure. Van den Bergh, Delarue, D'haeseleer (2013) noted that goal of the European Union is to decrease greenhouse gases by 20% in 2020 in comparison to the level from 1990.

Table 5 shows CO_2 emissions per capita of each European Union member country for the period between 2004 and 2012. This indicator can give us insight into trends in CO_2 emissions expressed in million tons. As it can be seen from the table, CO_2 emissions have a decreasing trend in most of the countries.

Table 5. CO2 emissions per capita in the EU

European Union member countries (million tonnes)	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
EU (28 countries)	8.7	8.6	8.6	8.5	8.2	7.5	7.8	7.5	7.4
Belgium	12.3	11.9	11.6	11.1	11.2	9.9	10.5	9.5	9.1
Bulgaria	6.4	6.5	6.8	7.3	7.1	6.1	6.4	7.2	6.6
Czech Republic	12.5	12.4	12.4	12.4	11.8	11	11.2	11	10.6
Denmark	10.2	9.5	10.9	10	9.3	8.8	8.8	7.9	7.1

(Table continues)

(Continued)

European Union member countries (million tonnes)	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Germany	10.7	10.5	10.6	10.3	10.4	9.6	10.1	9.9	10
Estonia	12.5	12.1	11.7	14.1	13	10.6	13.4	13.9	12.9
Ireland	11.4	11.6	11.2	10.9	10.5	9.2	9.1	8.3	8.3
Greece	9.9	10.2	10	10.2	9.8	9.3	8.7	8.5	8.2
Spain	8.2	8.4	8.1	8.1	7.3	6.4	6	6	5.9
France	6.9	6.9	6.7	6.5	6.4	6	6.2	5.7	5.7
Croatia	5.4	5.5	5.5	5.8	5.5	5.1	5	4.9	4.5
Italy	8.5	8.4	8.3	8.2	7.9	7	7.2	7	6.5
Cyprus	10.7	10.7	10.8	11	10.9	10.3	9.6	9	8.2
Latvia	3.4	3.4	3.7	3.9	3.7	3.4	4	3.7	3.6
Lithuania	3.9	4.2	4.4	4.8	4.7	4.1	4.4	4.6	4.7
Luxembourg	26.1	26.3	25.5	23.9	23.2	21.7	22.4	21.8	20.7
Hungary	5.9	5.9	5.9	5.8	5.6	5.1	5.2	5	4.6
Malta	6.6	6.7	6.6	6.8	6.7	6.4	6.4	6.4	6.7
Netherlands	11.1	10.8	10.6	10.5	10.7	10.3	10.9	10.1	9.9
Austria	9.6	9.7	9.3	8.9	8.9	8.1	8.7	8.4	8.1
Poland	8.4	8.3	8.7	8.7	8.5	8.1	8.7	8.6	8.4
Portugal	6.4	6.6	6.2	5.9	5.7	5.4	5	4.9	4.8
Romania	4.6	4.6	4.9	4.9	4.8	4.1	3.9	4.2	4.2
Slovenia	8.2	8.4	8.4	8.5	9	7.9	7.9	7.9	7.6
Slovakia	7.9	7.8	7.7	7.4	7.5	6.8	6.9	6.9	6.5
Finland	13.1	10.8	12.9	12.6	10.9	10.3	11.9	10.5	9.4
Sweden	6.2	5.9	5.9	5.7	5.4	5	5.6	5.2	4.8
United Kingdom	9.4	9.3	9.2	9	8.7	7.8	8	7.3	7.6

Source: European Environment Agency, Annual European Union greenhouse gas inventory 1990–2012 and inventory report, 2014, p. 12.

2.2 Sources of CO_2 emissions

During fuel combustion, carbon contained in the fuel is transformed through the oxidation process into CO_2. In an incomplete combustion of small fuel amounts of CH_4, CO and NMVOC occur. The most important greenhouse gas produced by fuel combustion is CO_2, which depends on the quality and type of fuel used. The burning coal produces the highest CO_2 emissions, followed by combustion of oil and natural gas. Fuel combustion generates other gases as well, such as methane (CH_4) and nitrous oxide (NO), along with indirectly produced greenhouse gases such as nitrous oxide (NO_x), and carbon monoxide (CO). CH_4 and N_2O emissions resulting from the combustion of fossil fuels are small, often less than 1% of total emissions. Combustion of biomass and biomass-based fuels also results in the emission of greenhouse gases. Total emission does do not include CO_2 emissions from biomass because CO_2 is previously absorbed from the atmosphere for the growth of biomass.

Table 6. Emissions by sector in the European Union member countries

Sector	**Share in 1990 total emissions in %**	**Share in 2012 total emissions in %**
Energy supply and use, excluding transport	63.0	59.7
Transport	13.9	19.7
Agriculture	11.0	10.3
Industrial processes	8.2	7.1
Waste management	3.7	3.1

Source: Commission to the European Parliament and the Council, Progress Towards Achieving The Kyoto And EU 2020 Objectives, 2014, p. 34.

According to Commission to the European Parliament and the Council (2014), energy use and supply were the two biggest factors in GHG emissions from energy from the combustion of fossil fuels, accounting for more than 60% of total EU emissions. Energy supply contains mostly emissions from heat production and public electricity together with other sources, specifically manufacture of solid fuels (coal) and petroleum refining. Energy use parameter mostly consists from the burning fuels in the commercial sectors which accounts for 17% and manufacturing industries which stand for 15% of energy emissions.

Sharp fall in emissions can be noticed in 2009 due to the economic crisis, followed by a slight improvement in 2010, and returning to a trend of decline. Furthermore, emissions are affected with climate condition when it comes to the residential sector. Logically cold winters require more heating and, on the other hand, cooling is much higher during hot summers.

In 1990, transport accounted for almost 14% of total emissions. By far, the biggest contributor is road transport, which is responsible for 94% of total emissions within transport industry, followed by aviation within national boundaries (domestic) with less than 2% of emissions. On the other hand, other ways of transport like railways have experienced a substantial decline in emissions due to switching railways to electrical power. According to Commission to the European Parliament and the Council (2014) transport emissions continued to grow, reaching 20% in 2012, having peaked in 2007, followed by a slight decline. Also, international aviation was considered eight times larger than domestic aviation emissions and that source is excluded from Kyoto Protocol target.

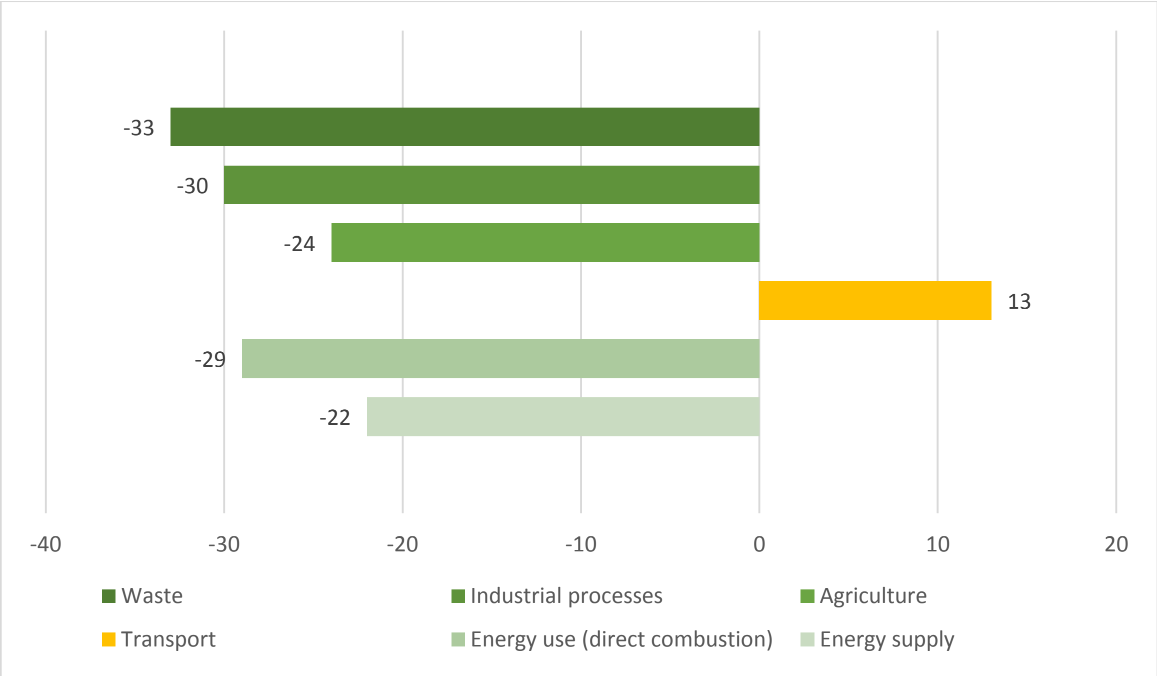
According to the same source, emissions from agriculture amounted for 11% in 1990 and declined to 10.3% in 2012. Methane (CH_4) and nitrous acid (NO_2) are the gases that were dominant in agriculture emissions, and they are 25 to 300 times more dangerous for global warming than carbon dioxide. All of these primary sources that came from agricultural soils, enteric fermentation, and manure management declined to around 24% in emissions since 1990.

Another industry that showed a decline in emissions were industrial processes that included non-energy emissions from chemical processes. Besides carbon dioxide as a major gas, fluorinated gases have a substantial impact also. The share of emissions from industrial processes was 8.2% in 1990 and it was decreased to 7.1% in 2012. Cement production, air conditioning devices, and refrigerators were biggest contributors to the emissions in this industry. Each of these segments is responsible for approximately 25% of emissions, and the rest is shared between chemical industry and metallurgy with combined 24% of share.

Compared to the other sectors, industrial processes showed one of the largest reductions in emissions since 1990 with over 30%. Due to higher temperatures and mass usage of air conditioning equipment and refrigerators, the consumption of F-gases increased for over eleven times since 1990. The most concerning thing is that these gases cause several thousand times more damage regarding global warming than carbon dioxide. In general, all the gases are in decline since 1990 in the European Union, but F-gases remain the only one that are increasing.

The last sector regarding emissions with the smallest share is waste, whose share in 2012 was 3%. One-third of the emissions from waste were reduced since 1990 when they accounted for 3.7% of the European Union total emissions. The biggest contributor to waste emissions are landfills, which account for almost 75% of emissions. Wastewater accounts for less than 25% of emissions. As with industrial processes, 30% reduction of emissions puts waste emissions as one of the sectors with the biggest reduction.

Figure 3. Greenhouse gases emission changes by sector, 1990–2013



Note: The graph is based on historical values, including 2013 approximated GHG emission inventories as reported by the Member States. The sector definitions used are as follows:
Energy supply: IPCC sectors 1.A.1+1.B; Energy use (direct combustion): IPCC sectors 1.A.2+1.A.4+1.A.5; Transport: IPCC sector 1.A.3; Agriculture: IPCC sector 4; Industrial processes: IPCC sector 2; Waste: IPCC sector 6.

Source: European Environment Agency, Trends and projections in Europe, 2014, p. 45.

Table 7. Share of renewable energy in gross final energy consumption

Countries	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
EU (28 countries)	8,3	8,7	9,3	10	10,5	11,9	12,5	12,9	14,1

Source: Statistical Office of the European Communities (EUROSTAT), Share of renewables in energy consumption up to 14% in 2012, 2014, p. 2.

Figure 3 shows that there is a significant drop of emissions in year 2013 compared to the year 1990 in all the sectors excluding transport. We can also notice that there is a massive drop in emissions from energy production while almost a quarter of emissions was decreased from 1990 until 2013. The main reason for such a reduction in emissions is an improvement in efficiency in the process of producing electricity from primary fuels.

Furthermore, switching to electricity generated from renewable energy sources had a big contribution as well. Table 7 shows that 14.1% of the energy in gross final energy consumption in 2012 came from renewables.

According to the expectation, energy supply emissions will continue to decrease between 2013 and 2020. This is mostly the case because of the renewable energy policy and the EU emission trading system. Furthermore, energy use and transport emissions are also expected to be lower. Since 1990 decline in emissions in the commercial and residential sectors can also be seen (17%), and it can be considered as one of the main factors in decreasing greenhouse gas emissions in the European Union. The decrease of emissions for transport is not that significant because of the increasing demand, which is, on the other hand, being compensated with the improved efficiency of the means of transport and promotion of the rail. According to the projections, emissions from both solvents and other sector and industry will eventually increase while agriculture sector is projected to remain almost stable until 2020. Also, waste emissions will continue to decrease.

2.3 Specific environmental issues that arise due to CO_2 emissions

Carbon dioxide, nitrous oxide and methane are greenhouse gases produced by regular activities and they are mixed in the entire layer of the atmosphere, making a thermal air envelope around the Earth. This layer prevents the loss of heat into space and contributes in making the Earth's climate suitable for life. Without reduction of greenhouse gases, the surface of planet Earth would be much colder than it is today, unfavorable for living creatures, cold and lifeless as the surface of Mars. The sun heats the Earth's surface. Earth heats up and emits thermal radiation. In this way, the face of the Earth reflects sunlight that came from the Sun to its surface. Greenhouse gases in the atmosphere absorb part of the radiation that leads to warming of the atmosphere, which is called the "greenhouse effect". Combustion of fossil fuels and deforestation that are absorbing bad gasses cause an increase in the carbon dioxide (CO_2) concentration in the atmosphere. With its activities, people also discharge other greenhouse gases, which affect the whole system, leading to additional global warming.

According to Panwar et al. (2011), scientists have predicted many negative scenarios caused by climate changes and because of that one of the primary concerns for humanity, today is climate change warns. They mention droughts and floods, different diseases, the risk of malnutrition and many other consequences that can be the result of environmental degradation and climate change. Undeveloped countries and low-income countries will experience most of the damage because they are not prepared for other scenarios. We are vastly contributing to the increased concentration of gases in the atmosphere that keeps the earth’s heat causing the overall temperature to rise. Panwar et al. (2011) say in their study that the amount of carbon dioxide increased 31% in the last 200 years only due to the deforestation causing the overall temperature to rise by 0.4 - 0.8 degrees Celsius. Many other environmental issues occur nowadays, and some of the likely global warming consequences are the rise of sea and ocean levels due to melting glaciers, and increased number and severity of extreme weather events such as storms, heat waves or floods. All of these events will indirectly cause even more damage as melting glaciers will primarily cause an increase in the amounts of water, only to be followed by a lack of water in some parts of the world. Additionally, the warmer environment will help spread different diseases and thus adversely affecting the public health. Many scientists have warned that the very uncertainty of what will happen is the best reason for keeping the effects of global warming at a minimum and reacting in advance. It is believed that the disproportionate impact of global warming will be a great motivation for the future migration of the population.

Global warming is already significantly affecting the climate and weather conditions on Earth. High temperatures extend the season droughts in Africa and, therefore, failing crops result in a lack of food and drinking water. North America, Europe and parts of Asia are in the mild climate and therefore in an advantageous position in comparison to the rest of the world. These areas will not turn quickly into areas where living conditions are tough. These areas must first go through a phase of transformation from moderate climate into harsher forms of weather, like tropical or desert. Areas that are already in a climate that hardly provides the conditions for life will have bigger problems, for example, sub-Saharan Africa. In these regions, life could simply disappear. There are two elementary methods of action about climate change prevention. Adapting to new weather conditions is the most likely scenario. Huge expenses are one of the reasons why prevention of these changes is a difficult process. Change in the way of thinking about energy consumption and energy, in general, is one of the requirements.

3 ENVIRONMENTAL PROTECTION AND ECONOMIC GROWTH

3.1 Environmental Kuznets Curve hypothesis

Literature in the field of environmental economics and ecological economics emphasizes the difference between the concepts of economic growth and economic development. The very concept of growth has been ignoring the direct impact that the environment has on the welfare, while the concept of development included a component of the environment (Pezzey, 1992). When analyzing the relationship between the environment and growth various formal models are used, which can be classified into the following groups: (1) model of optimal control; (2) endogenous growth models; and (3) models that are based on the so-called Environmental Kuznets Curve – EKC (Kordej-De Villa, 1999).

Since 1991 economists are dealing with the systematic study of the relationship of changes in national income (mainly in GDP) and the state of the environment (Yandle et al., 2002). The first step in this area has been attributed to Simon Kuznets, an American economist

(Kuznets, 1955). Kuznets showed that in the economic development the first phase of the rapid rise of the economy, the distribution of income among the population, or some defined social groups, is becoming more unequal. After reaching a certain level of development, a further increase in income leads to a gradual equalization of the difference between rich and poor. Change is a growth of GDP according to differences in wealth and has a bell-shaped curve (inverse letter U), which is today called Kuznets curve (Pravdic, 2005).

Environmental Kuznets Curve (EKC) is based on the model of the economy in which there is no return influence of the environment on the production possibilities and where trade has a neutral effect on the condition of the environment. The essence of the hypothesis is that the condition of the environment (measured by the concentration of a particular pollutant) is first deteriorating with the growth of per capita income until reaching a certain level of income per capita when the environmental conditions starts to improve (Kordej-De Villa, 1999).

On the x-axis is the income per capita, and on the y-axis is an indicator of the condition of the environment, measured by the concentration of a particular pollutant. The curve has the shape of an inverted "U". At lower levels of development, the effects of economic activities are limited only on an actual basis and on the existence of certain quantities of biodegradable waste. With economic development, the rates of exploitation of natural resources are higher than their regeneration rates, while the amount of waste and its toxicity are increasing. At higher levels of development, structural changes in the economy (the dominance of service industries) accompanied by increased environmental awareness, the enforcement of regulations, acceptable technology and higher expenditure for the environment result in a gradual reduction of degradation and improving the quality of the environment. Proponents of the EKC hypothesis see the economic growth as a means of enhancing the condition of the environment, rather than as a threat.

Opinions that greater economic activity inevitably undermines the environment is based on the assumption of a static technology, and unchangeable taste, while neglecting the factors that have a significant role in determining the impact on the environment: the structure of the economy, efficiency in the use of inputs, the possibility of substitution of scarce resources, the existence of clean technologies and successful management practices. To what extent these factors will affect the reduction of negative effects of economic activities on the environment will depend on the instruments of national policy. However, it should be noted that the economic growth alone is not sufficient for solving the environmental problems and is a necessary caution in interpreting empirical results (Arrow et al., 1995).

There are many empirical studies of EKC hypothesis. The results are different. Shafik and Bandyopadhyay (1992) estimated the EKC for ten different environmental indicators. The sample included 149 countries in the period from 1960 to 1990. Turning points (the point where improvement of environmental quality begins) appear at various levels of income per capita, depending on the indicator. A wide range of indicators that were used showed a very different picture of the relationship between the environment and economic growth. The authors concluded that it is possible to ‘outgrow’ certain problems of the environment, but that this mechanism is not automatic (Shafik and Bandyopadhyay, 1992).

Selden and Song (1994) estimated the EKC for four indicators of air quality (SO_2, NO_X, CO and dust particles). Of the 30 countries analyzed, 22 were in the group of countries with high income. Compared to other studies, the turning point was on higher levels of income: 8700 USD for SO_2, 11000 USD for NO_X, 6000 USD for CO and 10300 USD for dust particles.

Environmental economists, Grossman, and Krueger (1995), have recognized a similar regularity between the GDP and the environmental conditions. Kuznets curve was renamed in the Environmental Kuznets Curve. Observations of improvement of environmental quality with an increase in the wealth of a country or region relate primarily on pollution of air and water to some known pollutants: sulfur dioxide in the air, non-degradable organic pollutants in the environment, and heavy or toxic metals in the water. The regularity of EKC was established for some known pollutants, but also for the general state of the environment measured by specific indicators, as evidenced by a series of examples relating to North America, Western Europe, and Japan. These countries have become relatively rich (high GDP) in the second half of the 20th century. Existing data, obtained by monitoring the state of the environment, primarily through the measurement of concentrations of major pollutants in the air and the water, have confirmed the existence of the legality described by EKC. Although the upward part of the EKC is slow and can take over a century, the downward part is much faster and is influenced by changes in attitude of the population towards the environment and their aspirations towards a better quality of life. There also appears a sociological phenomenon: the willingness-to-pay costs to improve environmental quality. Acceptance of price for improvement of environmental quality becomes possible at the time when the population can pay: the hunger vanishes, there are conditions for a healthier life, a remarkable majority of people have the necessary material requirements for the quality upgrade of lifestyle (Hall, 2002).

3.2 Sustainable development

Lester Brown, the founder of World Watch Institute, has defined sustainable development and his definition is usually used today. In “Our Common Future” report by Brundtland Commission, it is stated: “Sustainable development is a development that meets the needs of the present, while not compromising the ability of future generations to meet their needs”. Nevertheless, there is no scientific and political agreement on the meaning of the “sustainable development” says Drljača (2012). The concept of sustainability has been used recently in a different context. Thus, in the literature the following formulation can be found: sustainable success, sustainable tourism, sustainable growth, sustainable production, sustainable excellence, and others. All of these terms describe the phenomena to which the philosophy of sustainable development is applied.

Rio Declaration and Agenda 21, the Johannesburg Declaration and the Plan of Implementation Plan, together with the principles of the UN Millennium Declaration (which are translated into the Millennium Development Goals) defined the global principles for sustainable development. These principles can be seen as:

- incorporation of environmental concerns into development policies,
- environmental internalization of costs by implementation of user/polluter pays (i.e. adaptation of external costs of environmental degradation into internal costs of polluters/users),
- the involvement of all stakeholders in the decision-making process through discussion and dialogue and the creation of partnerships,
- information and justice system access,
- the intergenerational and generational equity, including gender equality, and solidarity,
- subsidiarity principle (hierarchies and dependencies) between the local and global levels, and right to use financial resources and services that are required to meet basic needs.

The above values, characterize a foundation through which existing challenges and problems about sustainable development of a specific country should be discussed. In other words, they represent the tasks, objectives, and measures for the implementation of sustainable development policies.

Based on those mentioned above, sustainable development means:
- stable and reasonable economic development that can be sustained over a longer period,
- reduction of poverty by giving more power to the poor and providing them with better access to necessary resources and services,
- participation of all stakeholders in making decisions (local and national authorities, the business sector, civil society organizations, trade unions, professional organizations), sideways with promoting dialogue and providing confidence to develop social capital,
- cautious management and protection (the maximum degree possible) of nonrenewable resources,
- sustainable and rational usage of energy and natural resources (forests, water, land, etc.),
- decrease of waste amounts, effective control and prevention of pollution and reducing the maximum possible level of environmental risks,
- enlightening the education system and health care and also improvements regarding gender equality, and
- the preservation of traditions, cultural identity, and heritage.

Alarming state of the environment has become more and more frequently discussed in the last 50 years. Environmental problems of individual countries have been a subject of different talks. However, at the same time, severe global issues regarding environment required a change of behavior and actions of the entire world. There were opinions that the main cause of environmental degradation is economic growth. Until the end of the 1970s, the general indication was that economic growth conflicts with the improvement of quality regarding environmental protection and that change could be done only at the expense of other. That opinion added to the ways of defining and identifying priorities and objectives of economic policy. The growth of the economy was always more important than other policy objectives. Also, environmental issues are always at the very end of the process in the traditional way of decision-making. With the fact that the environment is an economic asset and a prerequisite of development, the situation began to change slowly. This was especially the case in less developed countries. Demands increased for such development, which is inside "ecological limits" of the Earth. Question, whether to grow, is now replaced with, how to do that?

The idea of sustainable development may offer the solution. Sustainable development means creating a competitive and lasting economy. Final objective of Europe 2020 strategy is increasing the energy efficiency of the European economy by 20 percent. Moreover, green technology will play a fundamental role in the reduction of the greenhouse gas emissions in the next ten years by 20 percent when compared to 1990 level. Nevertheless, the European Union expects its members to reduce the emission of greenhouse gas, regardless of the green technologies development. Therefore, the European Union member countries are positive about the use of renewable energy sources. The aim is that by the year 2020 close to 20 percents energy in Europe is made from renewable sources. The EU also expects additional savings in the energy sector because of the further integration of the European energy market. The methods we are using to produce energy from renewables enjoy the benefit of being sustainable, meaning they can be replicated during certain time. Also, what is very important is that the changes to the planet’s atmosphere are only marginal since the production of renewable energy produces only small amount of emissionsl in comparison to what is being released by the production using fossil fuels (Angelis-Dimakis et al., 2011).

Sustainable development policy, however, does not refer only to fighting greenhouse gas emissions and climate change. The goal is to increase the elasticity and resilience of the European economy towards climate change and to increase Europe's capacity to prevent and remediate the negative effects of natural disasters. Sustainability goal will probably not be automatically met by Environmental policy, but it will certainly help its development. While the idea of sustainable development is at the top of the social priorities list, it appears that economy responds slowly to the requirements. The models reveal the formal requirements for achieving sustainable development.

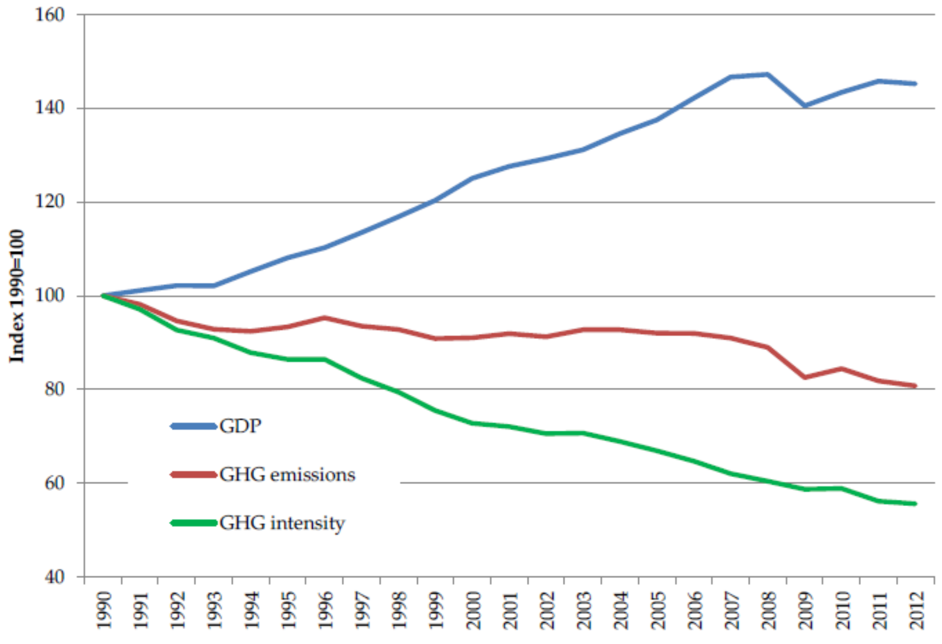
Sustainable development is a framework for determining strategies and policies for persistent social and economic progress, without damaging the environment and natural resources that are vital for future human existence. It is based on the idea that growth and development should not endanger the future of the coming generations. With that objective being set, environmental protection becomes much wider than the traditional view, which mainly dealt with the protection of the integrity of ecosystems and human health. The sustainable development concept nowadays is the source of modern social and economic trends since environmental damage is damage to the global society and vice versa. Actions to protect the environment bring benefits in the form of economic growth, employment, and competitiveness. The global economy must respond to human needs and justified aspirations, but development should be placed within the planet's ecological limits. The biggest challenges for decision-making are precisely the area where economic, ecological and other social objectives intersect. This is mainly linked to the different types of state intervention, distribution of income and the numerous types of subsidies. Composite environmental and economic decisions are followed with some unresolved issues. These questions are further motivation to the sustainable development definition. The revised sustainable development definition could, consequently, be the growth that offers future generations with at least as many opportunities or capacity for development as we currently have. The opinion that larger economic activity is necessarily damaging the environment is founded on the static technology assumptions. These opinions are overlooking the aspects that have an important part in defining the impact on the environment like the efficient use of inputs, economy structure, possible substitution of scarce resources, the existence of successful management practices and clean technologies. Individual countries policies influence the extent to which these factors would act to reduce the opposing effects of economic activity on the environment. Akella, Saini and Sharma (2009) discuss different aspects of renewable energy systems in their work. With environmental aspect being mentioned throughout the whole work, social and economic benefits of renewable sources are sometimes in the shadow. Sustainable development should not only be referred to in the context of environmental protection and economic growth – other aspects like job creation, education, social needs are important as well.

Regarding relations between pollution and economic growth, we can analyze the environmental Kuznets curve, inverted "U" relations between the levels of pollution and levels of economic development. The nature of this curve is very simple. Countries whose economic development is at a low level do not have enough resources to engage in the production of goods, and thus do not produce significant pollution. The growth in per capita income results in larger environmental damage. The turning point comes at a higher level of economic growth when countries are already wealthy enough to be able to take steps to reduce pollution. From the microeconomic perspective, a clean environment represents a luxury good for which people spend more as their wealth grows. Kearsley and Riddel (2010) said that the environmental Kuznets curve had been broadly disapproved for presenting an excessively optimistic view of economic growth effect on environmental degradation.

We return to the question of whether it is possible to break the link between pollution and economic growth. Certain reasons persuade us to believe that the relationship between the growth of pollution and economic growth could be broken. Because economic growth leads to increasing wealth, it will stimulate better protection of the environment in becoming more important and a higher priority. This means a faster substitution of resources and faster technological innovation. Although the environmental Kuznets curve is not a perfect instrument, which supports the hypothesis of decoupling between economic growth and pollution, its strength derives from the premise that economic growth is a way to ensure the protection of the environment and not the way to its degradation. It helps to identify many open questions of environmental protection in some of the most important areas of human activity, such as food production and energy.

Figure 5. shows that the European Union managed to decouple economic growth and emissions of greenhouse gases, and that decoupling happened in all member states. Between 1990 and 2012, the GDP of the European Union (combined) was increased by 45%. However, total greenhouse gases emissions were decreased by 19% in the same period, reducing by almost double.

Figure 4. Evolution of GDP (in real terms), GHG emissions and emission intensity (i.e. ratio of greenhouse gas emissions to GDP): Index (1990 = 100)



Source: Commission to the European Parliament and the Council, Progress Towards Achieving The Kyoto And EU 2020 Objectives, 2014, p. 34.

3.3 The challenge of reducing CO_2 emissions

In recent years the growing concern about the impact on the environment refers to the effect of global warming. The scientific community agrees in the fact that greenhouse gases have a severe impact on the composition of the atmosphere, which cause climate changes. Therefore, combined and methodical efforts to reduce carbon dioxide and other greenhouse gas emissions are necessary.

The largest contribution to CO_2 emissions is provided by the energy sector. Therefore, the greatest efforts in reducing the CO_2 emissions must be carried out by significant changes in the structure of energy systems. Many developed countries, after the two oil crises, agreed to these changes, while the transition to the use of natural gas, nuclear energy and measures of energy conservation has led to changes in energy supply, reducing oil dependence and increasing energy efficiency. These changes have had a substantial impact on the environment.

The resulting benefits to the environment were not sufficient to cope with the ever-increasing risks to climate changes. The laws of thermodynamics create certain boundaries that are insurmountable for the efficient use of energy. Natural gas has a positive effect on the environment but does not considerably reduce CO_2 emissions, while concerns about the risks of building nuclear plants are growing. It stresses the need for a global change of energy policies for dramatic reduction of CO_2 emissions in the long term. Renewable energy can play a significant role in the construction of such long-term energy policies. However, the influence of renewable energy sources in overall primary energy supply remains insignificant, despite progress in developing countries in the field of renewable energy technologies. The greatest barrier for considerable exploitation of RES can be seen in the main pricing mechanisms in the world energy market (Mourelatos, 1998).

In the current debate on the future of humankind, many views and approaches have been recorded. On the one hand, there is a belief that the current pace of growth of human population and its demands would quickly deplete all the basic natural resources, which will lead humankind to resource disaster. On the other hand, there is a belief that the dynamics of technological development do not provide evidence for the first claim, and that the current model of consumption of natural resources will not limit future economic growth says Ćulahović (2008). The world has now got to a point at which future environmental and economic needs have to be balanced with future energy demand says Sadorsky (2009).

The current technological development and the role of human capital have questioned arguments made by pessimists. They claim that nature sets the physical limits to economic growth and that we will soon reach the critical depletion of natural resources, which will drastically increase the cost of food, drinking water, energy, metals, paper and other natural raw materials. However, in real life, raw material prices have been steadily reduced, which has denied the theory that cheap raw materials lead to their rapid exhaustion. Paradoxically, while the prices of resources declined, established reserves of most natural materials have increased. According to Ponting (1991), the world has become more skilled in detecting new and exploitation of previous groundwater reserves of resources. This means that using technologies made resources more precise and realistic. For example, studies of oil reserves by traditional technologies are showing more and more "dry" wells, while today's technology is using seismic waves and computer processing of data. Using more advanced research technologies makes reserves look bigger, which in some way means that the reserves and resources have become a function of technology. Furthermore, many new resources have replaced the old, classical and scarce resources. Technology substitution is replacing the common resources: ceramics instead of tungsten, glass fiber instead of copper, polymers instead of metal, aluminum cans instead of steel cans, etc. Efficient use of materials is a result of greater knowledge about those materials. For example, technological progress of candles, over the carbon filament of tungsten, reduced the volume of energy needed to produce a unit of luminous flux. Refrigerators, automobiles, communications, computers and cameras are also typical examples of products that became lighter, smaller and better due to technological advances. Efficient consumption of energy can ensure cutting total energy usage and therefore greenhouse gas emissions. This is widely considered as a rather inexpensive method. Many agencies are recommending these processes at national and international levels. Khan et al. (2014) suggest that reducing a large amount of greenhouse gas emissions can be done without suffering real cost and provide potential net benefits. They also agree on the fact that most of the greenhouse gas emissions are a direct result of energy use in buildings that originate from the housing and the commercial sectors. These emissions take place due to on-site combustion of fuels used for heating, cooking cooling and providing power to the buildings.

The biggest concern for the scarcity of resources is in the energy sector. However, there are still no clear warning signs about the general lack of fossil fuels, because their proven reserves are sufficient for the next 70-100 years without other discovered resources such as, for example, oil shale, heavy oil and unconventional sources of natural gas (Ćulahović, 2001). It also seems that the concern for global energy problems, which are a consequence of excessive energy pollution, is much higher than the concern for the problems of resource availability. Under pressure from environmentalists, many technologies for the production of new forms of renewable energy are in an advanced stage of development. In addition to the promising development of energy production from renewable sources, there are many new solutions for the most efficient use of fossil fuels. Chiu and Chang (2009) paper contribution is to determine the optimal share of renewable energy supply for CO_2 emissions mitigation. They also considered the price of energy and GDP growth and their impact on carbon dioxide emissions. If the prices of energy are rising that would eventually affect the demand for the energy resulting in a reduction of carbon dioxide emissions. Furthermore, they concluded that if at least 8.38% of total energy supply comes from renewable energies, CO_2 emissions would eventually be mitigated. Sadorsky (2009) says in his work that the demand for energy is most likely going to increase by 50% between 2004 and 2030. For that reason, much money needs to be invested into energy supply industry. These costs are projected to be a stunning $20 trillion expressed in US dollars from the year 2006. This is considered an opportunity for the renewable energy sector to develop. Meanwhile, a lot of money needs to be invested in energy infrastructure in the coming years.

4 EU STRATEGY AND POLICY TOWARDS SUSTAINABLE ENERGY

4.1 Introduction to strategies and policies with historical review

To achieve the objectives related to environmental, economic and social aspects, the European Union has to deal with problems related to the energy. The EU is more and more faced with the increase in energy imports, unstable oil and gas prices, climate changes, increasing demand, and obstacles related to the highly competitive internal energy market. The European Union is the second largest energy market in the world. It must, therefore, impose itself as a world leader in demand management and promotion of renewable energy sources (Wysokińska, 2014).

Poor prognosis of global warming, particularly in the northern hemisphere have forced leading countries in the exercise of intense pressure for the adoption of international agreements, which would reduce current levels of carbon dioxide emissions. Countries and their governments have been discussing many agreements how to battle all these environmental problems. Countries that have signed Kyoto Protocol obligated themselves to reduce greenhouse gases in five years from 2008 by an average of at least 5.2% compared to the level measured in the year 1990 says Shafiei and Salim (2014). Different government incentives have supported this interest in fighting these issues. Some of the incentives that are meant to make these processes easier include feed-in tariffs, subsidies and so on.

Promotion of international management for climate changes started at the “First International Conference on world climate” in 1979 when it was determined that climate changes are a serious problem. All the governments were called to foresee and prevent potential climate changes caused by human activity, and which could have a negative impact on the welfare of humanity. Since then, many conferences and working bodies were held with the goal of establishing efficient management of climate changes. Framework Convention on Climate Change, launched in Rio de Janeiro in 1992, is the fundamental document that sought to prevent further global warming of the earth. Convention set principles of behavior, which were based on the belief of mutual, but also individual responsibility. Signing the convention, countries have accepted numerous obligations (reporting system on GHG emissions, the adoption of national programs for mitigating climate change and developing strategies customizations, etc.). It was demanded from industrialized countries to reduce GHG emissions on the level from the year 1990 until the year 2000 while the developing countries were left with some flexibility. The executive body of the Conference of State (Conference of Parties - COP) was formed, with two sub-organizations for scientific and technological advice and implementation. The Rio Declaration on Environment and Development contains 27 principles that define people's responsibilities in the protection of the environment, the right to growth and the obligations of countries in achieving sustainable development, taking into account the integrity and interdependence of planet Earth. In the Rio Declaration, the emphasis is on linking economic development with environmental protection, as the only way towards sustainability and long-term economic development. This Declaration speaks about the need to connect, collaborate and equal partnership between different stakeholders from all sectors (public, business and civil). Some of the principles of the Rio Declaration follow below. People have a right to a healthy life, and an important task for the international community is the extinction of poverty and reduction of variations in living standards in different parts of the world. Today's development must not jeopardize the need for development and environmental quality of current and future generations. Furthermore, states have the absolute right to use their natural resources, if not causing damage to the environment beyond its borders, but they should apply the precautionary approach to environmental protection. Environmental protection has to become an essential part of the development process to achieve sustainable development. It should work to reduce the rejection of unsustainable patterns of production and consumption. Pollutants in principle would have to bear the cost of pollution. For its implementation, sustainable development requires a holistic engagement of women, principles, creativity and courage of youth and experience of local and indigenous peoples whose identity, culture and interests should be recognized and supported.

Peace, development and environmental protection are inseparable. Since then, there have been eight sessions of the COP, and the main result is the signing of the Protocol on climate change in December 1997 in Kyoto. Dropping greenhouse gas emissions by 80–95% by the year 2050 compared to the level in 1990 is one of the aims of the European Union, brought by the European Council in October 2009 says Jägemann, Fürsch, Hagspiel and Nagl (2013). This would mean that whole power sector of Europe needs to be decarbonized. They also state in their work that this would cost between 139 and 633 billion Euros (expressed in 2010). When compared to the situation without carbon dioxide reduction target, this is estimated to be an increase of costs between 11% to 44%.

4.2 Kyoto Protocol

The Kyoto Protocol is an international agreement that requires its Parties by setting internationally mandatory emission reduction targets, connected to the United Nations Framework Convention on Climate Change, (UNFCCC, 2015). Kyoto Protocol is an international treaty adopted by consensus at the third session of the COP on 11 December 1997 in Kyoto, Japan. Its main feature is a set of mandatory targets for the reduction of greenhouse gas emissions for 37 industrialized countries.

According to the Protocol, developed countries are obliged to reduce collective emissions of GHGs emissions by an average of at least 5% compared to the base year, within the five-year period from 2008 to 2012. For developing countries, due to low levels of emissions per capita, a specific reduction of emissions is not provided (Ćulahović, 2008). Parties included in the protocol are allowed some flexibility in the way of reducing emission. Clean Development Mechanism is an example of such flexibility that is used to perform cooperative projects between the two countries. For example, the financing of the construction of high-efficiency power plants in developing countries, so that industrialized countries as a substitute for financing such projects would be given loans to reduce their emissions. Although the Protocol has not established a global system for emissions trading, it is possible to trade credits for GHG emissions of gases between the countries that have established limits on emissions.

By signing the Kyoto Protocol in 1997, the commitments concerning the emission reduction were set forth for all parties of Annex I which ratified the UNFCCC during the negotiations of the Kyoto Protocol. Duties are split into two periods, where the first period related to the period 2008-2012, while the second period runs from 2013 to 2020. OECD (2015) states that the country can fulfill its obligations as follows:

1. reducing GHG emissions domestically;
2. enhancing domestic CO_2 removals by forests; and
3. purchasing emission offsets from designated international carbon markets.

Table 8 provides an overview of the commitments undertaken by countries in the context of the above periods of the Kyoto Protocol. The table shows that the 23 EU member states fulfilled their obligations in the first period, emphasizing that they have decided to fulfill them together. Russia has taken the obligations of the first period, but not for another one. Turkey did not have any targets because it was not a signatory of the Convention during the negotiations of the Kyoto Protocol.

Table 8. Kyoto Protocol commitments

European Union member countries	**Quantified emission limitation or reduction commitment for first commitment period (2008-2012, from 1990 levels unless specified otherwise)**	**Quantified emission limitation or reduction commitment for second commitment period (2013-2020)**
Australia	+8%	−0.5% from 1990 level
Austria	−13%	−16% from 2005 level
Canada	−6%	N/A
Belgium	−7.5%	−15% from 2005 level
Czech Republic	−8%	+9% from 2005 level
Denmark	−21%	−20% from 2005 level
Estonia	−8%	+11% from 2005 level
EU	−8%	20% from 1990 level
Finland	0%	−16% from 2005 level
France	0%	−14% from 2005 level
Germany	−21%	−14% from 2005 level
Greece	+25%	−4% from 2005 level
Hungary	−6% from 1985−87 level	+10% from 2005 level
Iceland	+10%	−20% from 1990 level
Ireland	+13%	−20% from 2005 level
Italy	−6.5%	−13% from 2005 level
Latvia	−8%	+17% from 2005 level
Lithuania	−8%	+15% from 2005 level
Luxembourg	−28%	−20% from 2005 level
Netherlands	−6%	−16% from 2005 level
New Zealand	0%	N/A
Norway	+1%	−16% from 1990 level
Poland	−6% from 1988	+14% from 2005 level
Portugal	+27%	+1% from 2005 level
Russian Federation	0%	N/A
Slovak Republic	−8%	+13% from 2005 level
Slovenia	−8% from 1986	+4% from 2005 level
Spain	+15%[b]	−10% from 2005 level
Sweden	+4%[b]	−17% from 2005 level
Switzerland	−8%	−15.8% from 1990 level
United Kingdom	−12.5%	−16% from 2005 level

Note:

a Australia unconditionally pledged to reduce its emissions by 5% by 2020 from 2000 levels. This pledge was translated into a quantified emission limitation or reduction commitment of −0.5% from 1990 levels over 2013-20.

b As defined by the EU burden-sharing agreement (Council Decision 2002/358/EC).

c With the base year of 1995 for F-gases.

d Canada withdrew from the Kyoto Protocol in 2011.

e For emissions from non-ETS sectors only, as defined by the EU Effort Sharing Decision (Decision 406/2009/EC).

Source: UNFCCC, Kyoto Protocol, 2017

The Protocol contains a series of recommendations on how to reduce emissions with the new energy and transport policies and technologies. Likewise, these recommendations include new tactics and approaches for agriculture and forestry. Also, the Protocol emphasizes the need to promote technology transfer and ensuring the financial resources to cover the costs of those developing countries that fulfill their obligations under the Protocol. Following the adoption of the Protocol, numerous problems in its ratification occurred. The Protocol is expected to be implemented 90 days after ratification by at least 55 members of the Conference of Parties - COP, including the developed countries, which in 1990 were responsible for at least 55% of total emissions. Political disagreements in 2000 and 2001, which were mitigated by ratifying the Protocol in Russia and Japan, as well as rejection and abandonment of the US ratification of the agreement, have considerably slowed down the implementation of the Kyoto Protocol says Ćulahović (2008).

Table 9. Emissions covered by the Kyoto Protocol

Emissions	**1990**	**2005**	**2012**	**2020**
Total GHG emissions	5.626,3	5.178,2	4.544,2	
Of which domestic aviation	14,2	19,1	16,1	
Projections as compilation of MS data, WEM scenario				4.369,2(1)
-20% compared to Kyoto base year(2)				4.639,4

Source: Commission to the European Parliament and the Council, Progress Towards Achieving The Kyoto And EU 2020 Objectives, 2014, p. 34.

4.3 Europe 2020 strategy, targets, and initiatives

The financial crisis has fundamentally shaken the world economy. It discovered structural weaknesses in all major economies, as well as in the European Union. However, the financial crisis is an opportunity to learn something and spend the reform, so it would not repeat. Jose Manuel Barroso, European Commission President, said: "This crisis is a wake-up call, the moment when we must understand that access to 'business as usual' leads to a gradual decline in the second rank of the new global order. This is the decisive moment for Europe" (European Commission, 2010). As Europe is not to become a mediocre player on the world stage, the European Union has adopted a ten-year strategy - Europe 2020, which should reform the European economy.

Europe desperately needed reforms says Grguric (2011). The crisis has clearly shown the various "cracks" in the European economy. The European growth rates are lower than with major competitors such as the US or China, because of lower growth in productivity and lower rates of investment in research and development. The productivity of workers and the employment rate in the EU are additional problems that the European Union experiences. Finally, population aging is accelerating, which is a threat to the sustainability of European welfare states. These are just some of the problems to be solved by Europe 2020 strategy.

The first task of the Europe 2020 strategy is the creation of new jobs. However, the European Union is not interested in generating any jobs, but "better" jobs. The goal is to steer the European worker's better paid and more enjoyable tasks, which are jobs that require less physical and more intellectual work. However, economic development is not the sole objective of the Europe 2020 strategy. Europe wants to build a model of development that respects the wider environment, which includes not only the natural environment but also the society. Europe 2020 strategy attempts to create an inclusive society in which different groups have the opportunity to contribute to the progress of corporation, but also to enjoy the benefits of this progress. However, inclusive society also implies a reduction in disparities between richer and poorer regions of Europe. On the other hand, social progress should not go at the expense of nature. In short, the Europe 2020 strategy is a plan for economic development that is environmentally and socially sensitive.

The aim of this strategy are short-term policies to solve the problem of the economic crisis, but the implementation of medium and long-term reforms that would "cement" position as Europe's largest trading block and a major player on the global stage. To succeed, the European Union must ensure economic growth based on knowledge, which will be attended by all social groups and with the respect of nature. In essence, the Europe 2020 strategy is designed to provide Europe with a smart, sustainable and inclusive development.

Behind these abstract ideas, there are five measurable objectives:
1. To increase the rate of employment for the age group of 20 to 65 years to 75 percent.
2. To increase investment in R&D to 3 percent of GDP.
3. To reach climate-energy goals, "20/20/20" which include reducing greenhouse gases by 20 percent in comparison to the 1990 levels, increase the share of renewable energy to 20 percent and increase energy efficiency by 20 percent.
4. To reduce the number of students who drop out of school by 10 percent and increase the share of high education in the age group of 30 to 34 years to over 40 percent.
5. To decrease the number of people at a risk of poverty by 20 million.

These goals are unified and of critical importance to Europe's overall success. To be sure that each Member State applies the Europe 2020 strategy to its specific condition, the Commission suggests that the European Union goals are transformed into national targets. According to the newest official data that was published by the EEA in May 2014, in the countries greenhouse gas emissions were equal to 4522 million tons CO_2 equivalent in 2012. In most of the main emission categories, greenhouse gas emissions have decreased in the European Union between 2011 and 2012. The share of 65% of this total emission reduction accounted for energy. Economic recession across the European Union was another reason for a decrease in CO_2 emissions. The recession affected Europe as a whole, and half of the European Union member states experienced negative economic growth in 2012. Therefore, the 1.1 % decrease in CO_2 emissions came along in 2012. 2012 winter in Europe was on average colder than 2011 winter which led to a greater heating demand and resulted in higher emissions from households. According to the European Environment Agency (2014b), in 2020 the European Union countries are projected to reach levels 21% below 1990 levels, which is below its 20% individual reduction target.

Sustainable development means creating a competitive and sustainable economy. The European Union was an early leader in the development of "green" technologies. However, its dominance threatens North America and China. Therefore, further efforts are needed to maintain Europe's championship in green technologies, which are essential if the European Union member countries want to keep a high standard of living with increasingly scarce natural resources. Increasing the energy efficiency of the European economy by 20% is the final objective of the Europe 2020 strategy. Also, green technology will play an essential role in reducing greenhouse gas emissions in the next decade to 20% in comparison to 1990. However, the European Union requires its members to reduce greenhouse gas emissions, regardless of the development of green technologies. The European Union is optimistic in relation to the use of renewable energy sources for this reason. The goal is that 20% of Europe's energy should come from renewable sources by the year 2020. The European Union also expects savings in the energy sector due to the further integration of the European energy market. Overall, the development of green technologies and a shift to renewable energy sources should open over a million new jobs which are in line with policies for sustainable development. However, this does not refer only to reducing greenhouse gas emissions and fighting climate changes. The aim is to increase the flexibility of the European economy to climate change and Europe's capacity to prevent and remediate the adverse effects of natural disasters. Table 10 shows the progress of each member state in the direction of achieving the objectives for renewable energy share.

Table 10. Share of renewable energy in gross final energy consumption

European Union member countries	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
EU (28 countries)	8,3%	8,7%	9,3%	10%	10,5%	11,9%	12,5%	12,9%	14,1%
Belgium	1,9%	2,3%	2,7%	3%	3,3%	4,6%	5%	5,2%	6,8%
Bulgaria	9,6%	9,5%	9,7%	9,4%	10,7%	12,4%	14,4%	14,6%	16,3%
Czech Republic	5,9%	6%	6,4%	7,4%	7,6%	8,5%	9,3%	9,3%	11,2%
Denmark	14,5%	15,6%	15,9%	17,9%	18,6%	20,4%	22,6%	24%	26%
Germany	5,8%	6,7%	7,7%	9%	8,5%	9,9%	10,7%	11,6%	12,4%
Estonia	18,4%	17,5%	16,1%	17,1%	18,9%	23%	24,6%	25,6%	25,8%
Ireland	2,4%	2,8%	3,1%	3,6%	4%	5,2%	5,6%	6,6%	7,2%
Greece	6,9%	7%	7,2%	8,2%	8%	8,5%	9,8%	10,9%	13,8%
Spain	8,3%	8,4%	9,2%	9,7%	10,8%	13%	13,8%	13,2%	14,3%
France	9,3%	9,5%	9,5%	10,2%	11,2%	12,2%	12,7%	11,3%	13,4%
Croatia	13,2%	12,8%	12,8%	12,1%	12,1%	13,1%	14,3%	15,4%	16,8%
Italy	5,7%	5,9%	6,4%	6,5%	7,4%	9,3%	10,6%	12,3%	13,5%
Cyprus	3,1%	3,1%	3,3%	4%	5,1%	5,6%	6%	6%	6,8%
Latvia	32,8%	32,3%	31,1%	29,6%	29,8%	34,3%	32,5%	33,5%	35,8%
Lithuania	17,2%	17%	17%	16,7%	18%	20%	19,8%	20,2%	21,7%
Luxembourg	0,9%	1,4%	1,5%	2,7%	2,8%	2,9%	2,9%	2,9%	3,1%
Hungary	4,4%	4,5%	5,1%	5,9%	6,5%	8%	8,6%	9,1%	9,6%
Malta	0,3%	0,3%	0,4%	0,4%	0,4%	0,4%	0,4%	0,7%	2,7%
Netherlands	1,9%	2,3%	2,6%	3,1%	3,4%	4,1%	3,7%	4,3%	4,5%
Austria	22,7%	24%	25,6%	27,5%	28,3%	30,4%	30,8%	30,8%	32,1%
Poland	7%	7%	7%	7%	7,8%	8,8%	9,3%	10,4%	11%
Portugal	19,2%	19,5%	20,7%	21,9%	22,9%	24,5%	24,2%	24,5%	24,6%
Romania	16,8%	17,6%	17,1%	18,3%	20,4%	22,6%	23,2%	21,2%	22,9%
Slovenia	16,1%	16%	15,6%	15,6%	15%	18,9%	19,2%	19,4%	20,2%
Slovakia	5,3%	5,5%	5,9%	7,3%	7,5%	9,3%	9%	10,3%	10,4%
Finland	29,2%	28,9%	30,1%	29,8%	31,3%	31,2%	32,4%	32,7%	34,3%
Sweden	38,7%	40,5%	42,6%	44,1%	45,2%	48,2%	47,2%	48,8%	51%
United Kingdom	1,2%	1,4%	1,6%	1,8%	2,4%	3%	3,3%	3,8%	4,2%

Source: European Environment Agency, Annual European Union greenhouse gas inventory 1990–2012 and inventory report, 2014, p. 12.

4.3.1 Progress of the European Union member states towards 2020 targets for GHG emissions

With regards to the reduction of greenhouse gases emissions by 20% until 2020, the EU is well on its way to fulfilling the defined goal. Between 2012 and 2013, overall GHG emission of the EU member states decreased by 1.8%. Several significant developments occurred in 2013 regarding policy developments.

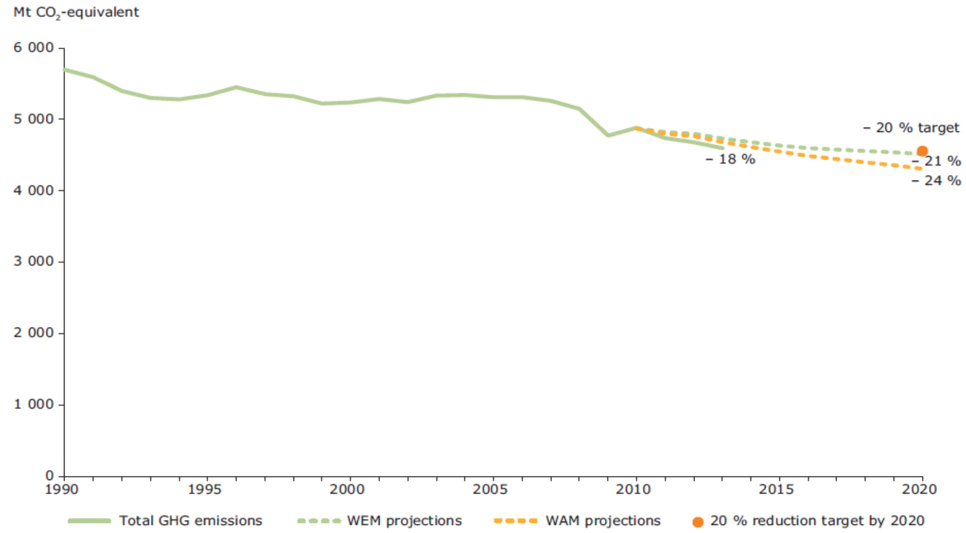
Among other things, Energy Efficiency Directive (EED) was adopted, as well as obligatory emission targets for new cars, a new regulation on fluorinated gases, and additional implementation of the eco-design legislation for water heaters and boilers. By maintaining this level of efforts put in by the EU Member States until 2020, there is a possibility of emission reductions that will exceed projected target of 24% (European Environment Agency, 2014a). Table 11 shows the main greenhouse gases emission trends and forecasts in the EU according to EEA.

Table 11. Main GHG emission trends and projections in the EU

	Total GHG emissions, excluding international aviation (scope: UNFCCC, Kyoto Protocol)	**Total GHG emissions, including international aviation (scope: climate and energy**
2011–2012	– 1.3 %	– 1.3 %
1990–2012	– 19.2 %	– 17.9 %
2012–2013	– 1.8 %	– 1.8 %
1990–2013	– 20.7 %	– 19.3 %
1990–2020 WEM	– 22 %	– 21 %
1990–2020 WAM	– 26 %	– 24 %

Source: European Environment Agency, Trends and projections in Europe, 2014, p. 45.

Figure 5. EU GHG emission trends and projections



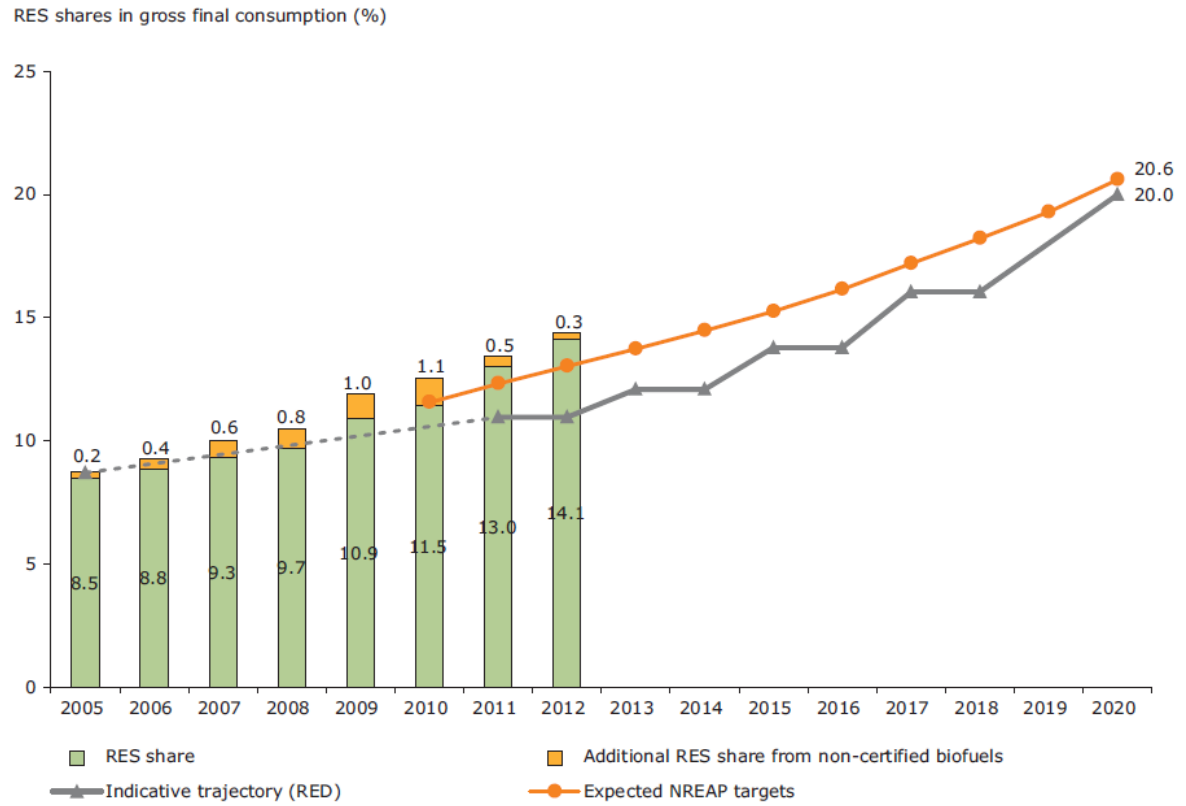
Note: The emissions presented in this graph include emissions from international aviation (which are covered by the EU climate and energy package but not by the Kyoto Protocol) and exclude emissions and removals from the LULUCF sector (carbon sinks).

Source: European Environment Agency, Trends and projections in Europe, 2014, p. 45.

4.3.2 Progress of the European Union member states towards 2020 targets for RES

According to the European Environment Agency (2014b), the portion of renewable energy in gross final energy consumption in 2012 was 14.1%. The amount exceeds the target of 13% set for the year 2012, established under EU member states' NREAPs. An average of 13.5% for 2011 and 2012 was also higher than the 11% target established by RED for that period. This indicates a scenario in which the EU will achieve its target of 20% with regards to renewable energy sources by 2020. Figure 7 illustrates EU progress to interim and 2020 renewable energy sources targets.

Figure 6. EU progress to interim and 2020 RES targets



Note: The EU's indicative trajectory is calculated from all political indicative RED trajectories. The other trajectory represents cumulative expected realizations according to Member States' NREAPs. For a consistent comparison across years, this figure separately provides the RES shares accounting only for biofuels complying with RED sustainability criteria, and the additional RES shares due to the other biofuels consumed in transport. However, the RES shares in gross final energy consumption reported by Eurostat (SHARES Results 2012) take into account all biofuels consumed in transport for the period from 2005 to 2010, and only biofuels are complying with RED sustainability criteria for years following 2011.

Source: European Environment Agency, Trends and projections in Europe, 2014, p. 45.

5 EMPIRICAL ANALYSIS: THE IMPACT OF ENERGY PRODUCED FROM RENEWABLE SOURCES ON CARBON DIOXIDE EMISSIONS

5.1 Literature review

A story about reducing CO_2 emissions dates back to the 1990s when this issue was first mentioned aloud. Reducing global warming and steady increase in temperatures forced many countries to sit down and discuss what can be done. This first led to the United Nations Framework Convention on Climate (UNFCCC) that was then followed by the Rio Earth Summit on 9 May 1992. Kyoto Protocol on 11 December 1997, which is considered an extended version of the convention, came after (De Jonghe, Delarue, Belmans and D'haeseleer, 2009). The most recent European action plan proposed a 20% decrease in CO_2 emission by the year 2020, which can be further extended to 30% if there is a mutual international agreement.

Many studies and works deal with carbon dioxide emissions. These studies have been conducted in various countries with numerous approaches and findings. In the research of natural resources, few approaches have been applied. Some researchers like Van den Bergh, Delarue, and D'haeseleer (2013) analyzed renewable energy sources deployment and its effects on CO_2 emissions but also how they affect the European Union Allowance prices, for the period between the years 2007 and 2010 for 12 countries of the European Union and Switzerland. More often, approaches include the connection between economic growth and its impact on the environment like the empirical analysis conducted by Kearsley and Riddel (2010). Their emphasis was on Environmental Kuznets Curve (EKC), a hypothesis that economic growth leads to increased pollution up to the moment when the economy reaches a certain stage and starts to decrease afterwards.

In addition to this approach Chiu and Chang (2009) included all 30 member countries of the OECD in their empirical analysis and covered a period from 1996 to 2005. They concluded that with the growth of the world economy the CO_2 emissions problem continues to worsen despite the increasing numbers of countries that have implemented renewable energy development mechanisms for reducing carbon dioxide emissions.

More authors like Sadorsky (2009), who examined G7 countries, agree that economic growth comes with staggering energy demands. Ohler and Fetters (2014) inspected the causal relationship between electricity generation and economic growth from renewables in 20 OECD countries between 1990 and 2008. In his work, Mourelatos (1998) deals with the conflicts among environmental and economic goals, influencing the development of renewable energy sources. Furthermore, strategic planning of the energy sector and impact of CO_2 reduction policies is examined in his work. While using various econometric techniques Khan et al. (2014) examined in their study the long-run relationship between GHG emissions and energy consumption for various groups of countries. Their result confirmed the aforementioned relationship.

Next, Marques, Fuinhas, and Pires Manso (2010) have done a panel data research regarding the motivation behind the deployment of renewable energy sources for a period between 1990 and 2006 in European countries. They managed three kinds of factors that either encourage or discourage renewable energy such as political, socioeconomic (including CO_2 emissions) and country-specific. Their research came to unexpected results like the one that renewable energy preferences were smaller with larger CO_2 emissions. A higher level of economic activity directly results in higher pollutions and, therefore, investments in renewable sources are smaller. On the other hand, they concluded that reducing energy dependency promotes the use of renewables.

Among researchers, there are also some doubts that the problem of greenhouse gases emissions can be solved, even if the renewable energy sources take a larger part in the portfolio of energy production. Chiu and Chang (2009) used panel data in their empirical approach that included all 30 OECD countries (at the time of the research) from 1996 to 2005. Their research showed a positive relationship between GDP growth and energy production despite the increases in shares of energy produced from renewable energy sources, which is explained by larger consumption of fossil fuels, and the increase inCO_2 emissions.

The second approach takes into account the connection between development of renewable energy sources and reduction of carbon dioxide emissions. Abolhosseini, Heshmati, and Altmann (2014) have done research on the effects of renewable energy development on CO_2 reduction. The empirical results in this research were founded on a panel data estimation using the European Union countries data observed from 1995 to 2010. They evaluated the effectiveness of renewable energy development on CO_2 emissions reduction, and found that increases in renewable energy production help reduce CO2 emissions. Furthermore, they have taken into consideration other elements such as technological innovation and market regulation findings. Instead, some researchers like Shafiei and Salim (2014) used the data for OECD countries from 1980 to 2011 to explore the determinants of CO_2 emissions and show how non-renewable energy consumption increases CO_2 emission and vice versa. OECD countries are largest energy consuming countries in the world with 41% of global energy consumption, which is still growing. In addition, the results of this research support the environmental Kuznets curve hypothesis between urbanization and CO_2 emissions. This implies that environmental degradation decreases at higher levels of urbanization.

However, according to our knowledge, only a few above-mentioned studies have investigated the relationship between renewable energy consumption and CO_2 emissions in the context of the European Union countries i.e. including all 28 member states. Therefore, this work attempts to fill in the gap in the existing literature.

5.2 Model

The empirical analysis covers 28 countries in the period from 2004 to 2012. These countries have put many efforts to help reduce CO_2 emissions with an attempt to reach 0 net CO_2 emissions by the year 2020 as in line with the global climate change objectives. These policy efforts include market regulations as well as public support to renewable energy production and development of environmentally friendly technology. Accordingly, the EU countries are leaders in the development of renewable energy and this is the reason why they are chosen to be included in this empirical analysis. In our estimation, carbon dioxide emissions are used as a dependent variable, and it is defined as man-made emissions of the 'Kyoto basket' of greenhouse gases. The variable does not include emissions and removals related to land use, land-use change and forestry (LULUCF); nor does it include emissions from international aviation and international maritime transport. Independent variables in this research are a share of renewables in gross final energy consumption, GDP per capita, final energy consumption, energy imports, environmental tax revenues and Total intramural R&D (Research and Development) expenditure (GERD).

This research is based on panel data. Panel data is relating to repeated observations (usually years) of the fixed units (usually states). Panel Data Analysis recently gained importance for several reasons. The first reason is related to the problem of a small number of observations (N) there are in our case study and analysis of time series and cross-sectional analysis. A number of observations are relatively small and amounts to 245. In contrast, thanks to the panel data, we can increase the number of observations and estimation of models with a large number of explanatory variables which is the case in analyses that use cross-sectional and time-series data. Specifically, following Abolhosseini, Heshmati and Altmann (2014), and Shafiei and Salim, (2014), we specify the following model using equation 1.

$$\ln CO_2pc_{it} = \beta_0 + \beta_1 SRES_{it} + \beta_2 \ln GDPpc_{it} + \beta_3 \ln FENCpc_{it} + \beta_4 ENIMP_{it} + \beta_5 ENVTAX_{it} + \beta_6 \ln RDEXPpc_{it} + \varepsilon_{it} \quad (1)$$

Where the dependent variable CO_2pc represents greenhouse gas emissions per capita of the country *i* in the period *t*; $SRES_{it}$ represents share of renewable energy sources in gross final energy consumption of country *i* in period *t*; $GDPpc_{it}$ represents GDP per capita of country *i* in period *t*; $FENCpc_{it}$ represents the final energy consumption of country *i* in period *t*, per capita; $ENIMP_{it}$ represents the net imports of energy as percentage of energy use of country *i* in period *t*; $ENVTAX_{it}$ represents the percentage of environmental taxes in total tax revenues of country *i* in period *t*; $RDEXP_{it}$ represents the total expenditure of country *i* in research and development per capita in period *t*; and ε_{it} is the random error depending on whether the model is estimated using fixed effects, random effects models or ordinary least squares (OLS).

Table 12. Variables

Variable	**In formula**	**Source**	**Expected sign**
Share of renewable energy in gross final energy consumption	SRES	European Environment Agency (EEA) - EUROSTAT	Negative (-)
GDP per capita	GDPpc	WORLD BANK	Positive (+)
Final energy consumption	FENCpc	EUROSTAT	Positive (+)
Energy imports, net	ENIMP	WORLD BANK	Positive (+) / Negative (-)
Environmental tax revenues share	ENVTAX	EUROSTAT	Negative (-)
R&D (Research and development) expenditure share	RDEXP	EUROSTAT	Positive (+) / Negative (-)

The variable of interest in this analysis is Share of renewable energy sources in total consumption. Calculation of the renewable energy share includes four different sub-indicators that are heating and cooling, transport, electricity and overall renewable energy sources share. Data has been collected annually from the year 2004. As mentioned by Eurostat, fundamental data for energy quantities are fuel specific units. These units are converted to common energy units like kiloton of oil equivalent (KTOE) for the purpose of calculation. There are some boundaries regarding a harmonized methodology since in some countries data collection systems and reporting are still at an early stage of development. However, firmly agreed internal methodology is the basis of most of the data. To conclude, this indicator measures how excessive is the use of renewable energy and by implication, the degree to which renewable sources substitute fossil and/or nuclear fuels. The expected sign was a minus, as we believe that the increase in share of renewable energy sources results in decrease of CO_2 emissions.

Furthermore, we include a set of control variables. The included control variables are frequently used in environmental and energy research (Marques et al., 2010; Marques and Fuinhas, 2012; Wong et al., 2013). Gross domestic product (GDP) per capita is included in our model as the key and frequently used growth indicator. We believe that the growth of the GDP per capita indicates more developed economy and therefore more energy production which will result in more CO_2 emissions. This is why the expected sign was a plus. Data for this variable are expressed in current U.S. dollars. The source of data for this variable is World Bank national accounts data.

Final energy consumption per capita is another control variable used in research. Eurostat provides data for this variable, which is measured annually and expressed in million TOE (tons of oil equivalent). For this research, we calculated values per capita. This is done in the same way as for the GDP per capita, dividing the data by the population. According to Eurostat, this indicator shows the sum of the energy provided to the final consumer for all energy uses. Final Energy Consumption includes total energy provided to industry, households, transport, agriculture and services. On the other hand, it excludes the energy industries themselves and the process of delivery to the energy transformation sector. This justifies our assumptions that the expected sign is a plus and that with the increase in final energy consumption, the CO_2 emissions will rise. According to the Eurostat data, for measuring the energy consumption at a final place of its use, this quantity is relevant. Also, it can be used for comparing the result to the Europe 2020 targets.

Net energy imports are an important variable estimated since less production of energy domestically is assumed to be associated with lower CO_2 emissions. The source of this data is the International Energy Agency (IEA), and it is measured in oil equivalents. It can be assumed that if a country imports energy it will produce less energy since the overall needs for energy would be partially satisfied with imports.

The variable environmental tax revenues are measured as the percentage of total revenues from taxes and social contributions. The essential purpose of environmental taxes is to incorporate environmental costs into the costs of production and provide right market incentives structures that would potentially decrease damage to the environment relying on costs approach. Companies would then be forced to include the effects of their actions on the environment in the price of products or services. Hence, it is important that the amount of the tax applied equals to the cash value of the damage caused to the environment. Therefore, the expected sign is negative meaning that the higher environmental tax revenues are, the smaller CO_2 emissions are.

Total revenues from environmental taxes include taxes on pollution, transport, resources and energy. EUROSTAT publishes this indicator for the European Union Member States, Iceland, Norway, and the European Union (aggregated data). The time series covers the period 2000-2011.This indicator is selected as a main Resource Efficiency Indicator used for the evaluation of the progress towards the targets and objectives of the Europe 2020 Initiative.

Total intramural R&D (Research and development) expenditure (GERD) is used in this research as a proxy for countries' level of technological development and innovative capability. We believe it is important to include this variable in the model not only to control for the differences in the levels of technological development among countries, but also to investigate the impact of innovative efforts on CO_2 emissions. Given the right market incentives, smart regulation in the EU is designed to promote investments in the development of new or improved market friendly technology. We believe that this variable may pick up some of the effects of these efforts, and attempt to investigate the nature of the relationship in the EU context. At least it seems reasonable to assume negative relationship between R&D expenditures and CO_2 emission. The R&D data are collected annually by the European Union Member States based on a legal obligation. Eurostat research and development database holds national data from the year 1980 until today, even though the data accessibility varies according to the country.

Descriptive statistics and correlation matrix are presented in Table 13 and Table 14.

Table 13. Descriptive statistics

Variable	**Observations**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
CO_2 emissions (million tons)	252	10.44	3.99	4.76	28.39
Share of renewable energy in gross final energy consumption (percentage)	252	13.66	10.77	0.30	51
GDP per capita (US$)	252	30818.09	20511.49	3331.09	113738.70
Final energy consumption (million tons of oil equivalent)	252	41.15	0.40	0.40	223.40
Energy imports (% of energy use)	252	53.64	30.45	-65.74	99.87
Environmental tax revenues (% of total revenues from taxes and social contributions)	252	7.44	1.63	4.08	12.21
R&D (Research and development) expenditure (Euro per inhabitant)	252	416.06	407.55	10.9	1464.90

Table 14. Correlation matrix

	GHGpc	SRES	GDPpc	FENCpc	ENIMP	ENVTAX	RDEXP
GHGpc	1.0000						
SRES	-0.3586	1.0000					
GDPpc	0.6662	-0.0486	1.0000				
FENCpc	0.8209	0.0012	0.8370	1.0000			
ENIMP	0.1256	-0.2575	0.0866	0.1668	1.0000		
ENVTAX	-0.0195	-0.1511	-0.2773	-0.2151	-0.1289	1.0000	
RDEXP	0.4285	0.3207	0.8509	0.7144	-0.1785	-0.3258	1.0000

5.3 Results

The simplest way to estimate panel data is to use the data in a combined (pooled) form. In this case, the model is estimated using the ordinary least squares method (OLS). The analysis is first carried out using OLS regression in which we have ignored the nature of the panel data (there is no difference between countries or period of observation). Table 15 presents the results obtained for the pooled OLS.

Table 15. Results: OLS estimation

	Model
SRES	-0.014*** (-13.11)
GDPpc	-0.044 (-0.83)
FENCpc	0.707*** (17.56)
ENIMP	-0.001*** (-2.86)
ENVTAX	0.025*** (3.60)
RDEXP	-0.014 (-0.48)
R-squared	0.77
Adj R-squared	0.76
N	245

Note: t statistics are in parentheses

*** Denotes significance at the level of 1%; ** Indicates significance at the level of 5%

* Indicates significance at a level of 10%

According to the results of the OLS estimation, for the variable of interest SRES, the negative sign is expected and is significant at the level of 1%. This means that an increase of share of energy produced from renewable sources would result in a reduction of CO_2. Different from what we expected, GDPpc has a negative sign and it is not statistically significant. Both FENCpc and ENVTAX have a positive sign and are statistically significant at 1% level. On the other hand, ENIMP and RDEXP have the expected negative sign.

The OLS estimation is not an appropriate method of estimation in panel data and in this research it serves as a reference for checking the presence of multicollinearity in the model. This is accomplished by calculating the Variance Inflation Factor (VIF). The VIF statistics suggest that multicollinearity is present between GDPpc and RDEXP (see Appendix 1).

In this master's thesis, we use the random effects model and the fixed effects model. In the fixed effects model we assume that the individual effect is constant for each unit of observation. (Individual effect becomes part of the constant, but varies according to the subjects). The fixed effects model is based on the assumption that a particular sequence characterizes every time unit section and each period. This assumes that the deviation εit satisfies the requirements of the classical normal linear regression model.

Furthermore, the choice between the FE and RE models is made using Hausman's and Breusch-Pagan Lagrange multiplier (LM) test. The results for the FE and RE values of the model and these tests are presented in Table 16.

Table 16. Results: FEM and REM

	FEM	**REM**
SRES	-0.016*** (-8.73)	-0.015*** (-10.11)
GDPpc	0.009 (0.34)	0.014 (0.55)
FENCpc	0.762*** (13.56)	0.714*** (15.44)
ENIMP	-0.000 (-0.65)	-0.000 (-1.08)
ENVTAX	0.019*** (4.39)	0.018*** (4.30)
RDEXP	0.023 (1.14)	0.008*** (0.44)
R-squared (within/between)	(0.78 / .73)	(0.77/0.75)
F test/Wald chi2 **Prob>F**	125.75 0.000	811.28 0.000
N	245	245

Note: t/z statistics are in parentheses
*** Denotes significance at the level of 1%
** Indicates significance at the level of 5%
* Indicates significance at a level of 10%

We used Hausman test to check the null hypothesis that the additional orthogonal condition for RE estimator is valid. The null hypothesis for the Hausman's test states that the difference in coefficients between the FE and RE specifications is not systematic. Thus, a small p-value (<0.05) suggests rejection of RE Specifications.

Moreover, we have to take into account the distribution of the error processes and homoscedasticity of the residuals, and correlation of residuals within and across the panels. If the variance of random error is different for some observations and if the residuals show a systematic deviation for various values of the independent variables and systematic correlation, the assumptions of homoscedasticity and of no serial correlation in the data are not satisfied. To test for the presence of heteroscedasticity, serial correlation and cross-sectional dependence in the data, we use appropriate tests. Panel data often includes complex error processes associated with the presence of heteroscedasticity and serial correlation.

This is why, before choosing an applicable estimator to observe the estimates of CO_2 emissions, it is necessary to perform diagnostic tests. These include heteroscedasticity, the cross-sectional dependence, and serial correlation tests. Complicated error processes are often part of the panel data, and they include panel heteroscedasticity. This means that among countries different variances of the error processes occur. Besides, error processes in coexistent correlation (i.e. country *i* shows huge errors at time *t*) will frequently be linked with significant errors for country *j* at time *t*, and serial correlation may be present. In regard to this, for groupwise heteroscedasticity we used Modified Wald test in fixed effect regression model. Also, we used Pesaran's test of cross sectional independence and contemporaneous correlation along with Wooldridge test for autocorrelation in panel data. The results indicate the existence of heteroscedasticity together with cross-sectional dependence and serial correlation between the variables in the model (see Appendix). In order to address this issue, we used a Beck and Katz’s (1995) approach.

With regard to the results of the FE model, Wald test for heteroscedasticity in the FE model, test for autocorrelation in panel data by Wooldridge and test for cross-sectional dependence, we used suggestions from Beck and Katz (1995) and performed OLS with panel-corrected standard errors using Prais-Winsten transformation.

Table 17. Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

	Model 1	Model 2	Model 3
SRES	-0.006*** (-2.74)	-0.009** (-3.72)	-0.009*** (-3.83)
GDPpc	0.115*** (2.65)	0.312*** (6.34)	0.253*** (5.34)
FENCpc	0.525*** (9.62)		
ENIMP	0.000 (0.30)	0.000 (0.81)	0.000 (1.06)
ENVTAX	0.013*** (3.15)	0.012*** (2.66)	0.013*** (2.90)
RDEXP	0.037** (2.09)		0.049** (2.09)
R-squared	0.78	0.78	0.78
F test/Wald chi2 Prob>F	3.48e+07 0,000	1.93e+07 0,000	1.22e+07 0,000
N	245	245	245

Note: Z statistics are given in brackets (PCSE); all regressions include constant, country and time dummies (not reported in the table).
*** Denotes significance at the level of 1%
** Indicates significance at the level of 5%
* Indicates significance at a level of 10%

The results of econometric analysis are shown in the Table 17. Precisely, the table shows estimates for OLS fixed-effect panel data together with PCSE panel-corrected standard errors. Table 17 includes the estimated model results which include the baseline specification (model 1), and also models 2 and 3 which are simplified from model 1 without two control variables FENCpc and RDEXP due to the problem of multicollinearity and the econometric consequences of the energy consumption variable. With regard to the latter, according to Jaforullah and King (2017) the energy consumption variable can have several unhelpful effects on the econometric results when included as independent variable in CO_2 emissions models. Specifically, it may generate under- or overestimates of both the total effect of income on CO_2 emissions, and could also affect other control variables in the model, for example, that the energy consumption variable may lead to systematic volatility in the model's coefficients in case of omitted variable problem. This is why we tested for the robustness of the obtained results when excluding the Energy consumption variable from the models 2 and 3 to be estimated. Essentially, it seems important to note that the model is robust (the significance and the size of the obtained coefficients remain unchanged) to changes in the specifications of model. Interpretation of variables' coefficients refers to, on average, ceteris paribus conclusions. It should be noted that we included country-specific effects (country dummy variables). This was done in order to take into account for the disregarded country specific effects, time-invariant, and time dummies to check for the effects that are time specific e.g. to control for the economic crisis reflected in large decline of output in years 2008 and 2009. In addition, the possible delayed effects linked with time specific variation in the times after the crisis are included. Additionally, following Wooldridge (2003) we claim that coefficients are estimated with better precision when we include time dummies. Some of the variation in the dependent variables is absorbed by the independent variables in the model when time dummies that are time specific are absent. In most cases, we found that both time and country specific effects are significant in most cases, however they are not reported here due to space limitations (see Appendix 1).

Generally, all variables included in a model have the expected sign. The only exception is that the environmental tax variable has a positive sign. We find that share of renewable energy source, as our variable of interest, significantly decreased level of CO_2 across the EU countries. The extent of the coefficient reflects on economic importance of increases in share of renewable energy source that negatively impacts CO_2 emissions (i.e. 1% rise in share of renewable energy in gross final energy consumption leads to decrease in CO_2 emission per capita of about 0.006 percent). Overall, the empirical results support the hypothesis that there is a significant and negative effect of the use of energy gained from renewable sources and CO_2 emissions in the European Union countries.

It is also found that CO_2 emissions are significantly impacted by the GDPpc variable. In addition, both FENCpc and ENVTAX are significant at 1% level and have a positive sign. The results obtained with respect to variable ENVTAX are somewhat unexpected. Specifically, the results for this variable suggest the positive relationship between environmental tax and CO_2 emission. A possible explanation for the obtained results for variable ENVTAX could be that higher revenues from environmental taxes will not necessarily be linked to higher tax rates, as a scenario with high consumption of lightly taxed goods is possible. Additionally, a more effective tax may diminish the base of the environmental tax, thereby reducing total revenue from environmental taxes. It is worthwhile noticing that most of the revenues from environmental tax come from taxes on motor fuels and demand inelasticity from these goods is such that these taxes do not cause reductions in the base of the tax. Actually, these taxes are far from consistent with the environmental damage generated by motor fuel consumption (Obrien and Vourch, 2002; Albrecht, 2006). The EU-28 countries have a relatively high GDP per capita and are considered developed countries. This means that the tax rate should be high enough to cause a subtle energy consumption reduction. Pearce (1991) showed that a decrease in carbon emission might not be the case unless the associated elasticities are recognized with acceptable certainty. On the other hand, ENIMP has a negative sign and is not significant. This outcome indicates that the dependence on energy imports of EU countries is not associated with lower CO2 emissions.

CONCLUSION

CO_2 emissions have been put into the energy policy spotlight because of the global warming issues. Reduction of fossil fuels dependence is crucial if there is any serious effort to deal with global warming. Increased consumption of energy gained from renewable sources is likely to be caused by increased concern over global warming and generally increases in carbon dioxide emissions. Shifting completely to renewables is not possible now due to the various economic and technological problems. However, fulfilling the energy mix with clean energy is definitely a huge step in that direction. Some of the policies that are related to each country effectiveness when it comes to energy mix will have to be revised and further assessed. The reason is different infrastructural and geological structure of each country that renewable energy sources depend on. There are more obstacles for increasing energy efficiency including old electrical grids, which are also not adjusted for renewables. Countries will have to invest much time and capital into finding mechanisms and establishing long-term policies in order to overcome these kinds of problems.

The thesis points out the advantages and disadvantages inherent in the various renewable energy sources. Even though production of energy from renewable sources is considered as a clean and efficient method, certain adverse effects on the environment occur in this process. Potential negative effects of the renewable energy sources on the environment can include ones such as: local ecosystems may be affected by the construction of the plant, changes in landscape and soil erosion can happen, occurrence of hazardous wastes, CO_2 emissions can be produced during the burning process, there can be a drop in water motion and circulation, changes of sea ecosystem, possible air pollution, etc.

In terms of establishing level at which countries fulfill their promises and obligations regarding the use of energy from renewable sources and decrease of carbon dioxide emissions, this thesis points out the fact that most European countries experience energy-led growth, but also consume a lot of energy. As this thesis showed, greenhouse gases emissions rise with the growth of GDP as a measure of economic growth. This can be explained by using Kuznets curve. It shows the relationship between GDP levels and pressure on the environment. Simply said, in order to reach certain progress when it came to reducing the CO_2 emissions and negative impacts on the environment, a parallel increase in GDP is required.

The analysis has proven that there are strong indicators that point to a significant decline in emissions in all sectors except transport. There can also be seen the massive decline of emissions generated from energy. Almost a quarter of emissions was decreased from 1990 until 2012. The main reason for such reduction in emissions is an improvement in efficiency in the process of producing electricity from primary fuels. Furthermore, switching to electricity generated from renewable energy sources and cleaner fuels like natural gas is another reason. In 2012, the share of renewables reached 14.1% of the gross final energy consumption in the EU. All this indicates a positive relationship between energy production from renewable energy sources and reduction of CO_2 emissions.

The main goal of this study was to investigate the impact of energy produced from renewable sources on carbon dioxide emissions in EU countries. The empirical analysis covered 28 European Union countries in the period from 2004 to 2012. The principal variable of interest was Share of energy from renewable sources in total consumption. We used fixed-effect panel data estimates with PCSE panel-corrected standard errors. This analysis provided strong evidence of a causal relationship between renewable energy consumption and CO_2 emissions. With regards to this government should design and implement effective support policies to promote investment in new renewable energy technologies in order to achieve steady and sustainable growth in renewable energy use.

Recommendation for further actions regarding the reduction of carbon dioxide emissions and consumption of renewable energy sources, based on the results of the research of the European Union members, is to keep the positive way of fulfilling the defined goal - the reduction of GHG emissions by 20% until 2020. The EU member states have to continue and maintain decreased level of overall GHG emission, and also make significant developments in years to come in terms of policy developments. By maintaining this level of efforts done by the EU Member States until 2020, there is a possibility of emission reductions that will exceed projected target of 20% and continue its trend of extension in the future years as well. It is very important to pay attention to raising the awareness of the environmental protection. This could play a very important role when it comes to implementation of different policies associated with environmental degradation. It would be much easier to overcome climate change problems if these policies are not only considering energy sector but are also integrated into other industries like education, manufacturing, transport, etc.

However, there are many limitations that need to be stated. It is important to state that this study could be improved by using a more frequent data set (for example monthly or quarterly data) which would give a much larger number of observations. The other limitation is related with a potential omitted variable bias. By including additional control variables this research could be even more improved.

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APPENDIXES

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Appendix A. List of Abbreviations

1. CH_4 – Methane
2. CO – Carbon Monoxide
3. CO_2 – Carbon Dioxide
4. COP – Conference of Parties
5. EEA – European Environment Agency
6. EED – Energy Efficiency Directive
7. EKC – Environmental Kuznets Curve
8. ENIMP - Net Imports of Energy of Country in Period
9. ENVTAX - Environmental Taxes in Total Tax Revenues of Country
10. ETS – Emissions Trading System
11. EU – European Union
12. EUROSTAT - Statistical Office of the European Communities
13. FEM – Fixed Effect Model
14. $FENC_{pc}$ – Final Energy Consumption per capita
15. GDP – Gross Domestic Product
16. GDP_{pc} – Gross Domestic Product per capita
17. GERD – Research and Development Expenditure
18. GHG – Green House Gases
19. GHGpc – Green House Gases per capita
20. GW – Gigawatts
21. HFCs – Hydrofluorocarbons
22. IEA – International Energy Agency
23. IPCC – Intergovernmental Panel on Climate Change
24. KTOE – Kiloton of Oil Equivalent
25. LM - Breusch-Pagan Lagrange Multiplier
26. LULUCF – Land Use, Land Use Change and Forestry
27. MW – Megawatts
28. NMVOC – Non-methane Volatile Organic Compounds
29. NO – Nitrogen Oxides
30. NO_2 – Nitrous Oxide
31. NREAPs – National Renewable Energy Action Plans
32. OECD – The Organization for Economic Cooperation and Development
33. OLS – Least Squares Method
34. PFCs – Perfluorocarbons
35. R&D – Research and Development
36. RDEXP - Total Expenditure of Country in Research and Development in Period
37. REM – Random Effect Model
38. RED – Renewable Energy Directive
39. RES – Renewable Energy Sources
40. SF_6 – Sulfur Hexafluoride

41. SO_2 – Sulfur dioxide
42. TOE – Tons of Oil Equivalent
43. TWh/y – Terawatt-hour per year
44. UK – United Kingdom
45. UN – United Nations
46. UNFCCC – United Nations Framework Convention on Climate Change
47. USD – United States Dollar
48. VIF – Variance Inflation Factor
49. WEM – World Energy Model

Appendix B. Ordinary least squares

pwcorr logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc

	logGHG	Shareo~n	logGDP~a	logFin~c	Energy~t	Enviro~s	lnRDpc
logGHG	1.0000						
Shareofren~n	-0.4046	1.0000					
logGDPperc~a	0.5576	-0.0391	1.0000				
logFinalen~c	0.7247	0.0757	0.7995	1.0000			
Energyimpo~t	0.0525	-0.2575	0.0980	0.0607	1.0000		
Environmen~s	-0.0268	-0.1511	-0.3525	-0.3128	-0.1289	1.0000	
lnRDpc	0.4825	0.1375	0.9363	0.7922	-0.0763	-0.3962	1.0000

regress logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc

Source	SS	df	MS
Model	20.9486242	6	3.49143737
Residual	6.21843474	238	.026127877
Total	27.167059	244	.111340406

Number of obs = 245
F(6, 238) = 133.63
Prob > F = 0.0000
R-squared = 0.7711
Adj R-squared = 0.7653
Root MSE = .16164

logGHG	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Shareofrenewableenergyingrossfin	-.0147297	.0011236	-13.11	0.000	-.0169432	-.0125162
logGDPpercapita	-.0444583	.0535204	-0.83	0.407	-.1498925	.0609758
logFinalenergyconspc	.707795	.040314	17.56	0.000	.6283772	.7872128
Energyimportsnet	-.0011498	.0004016	-2.86	0.005	-.0019409	-.0003587
Environmentaltaxrevenues	.0256048	.0071076	3.60	0.000	.011603	.0396066
lnRDpc	-.0149294	.0311335	-0.48	0.632	-.0762618	.0464029
_cons	12.08659	.7675774	15.75	0.000	10.57448	13.5987

. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of logGHG

chi2(1) = 2.48
Prob > chi2 = 0.1151

. estat vif

Variable | VIF 1/VIF

lnRDpc	14.16	0.070597
logGDPperc~a	13.72	0.072898
logFinalen~c	2.90	0.344473
Energyimpo~t	1.40	0.715822
Shareofren~n	1.37	0.731399
Environmen~s	1.27	0.789521
Mean VIF	5.80	

Appendix C. Fixed effects model

. xtreg logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc, fe

Fixed-effects (within) regression Number of obs = 245
Group variable: V2 Number of groups = 28

R-sq: within = 0.7815 Obs per group: min = 8
between = 0.7394 avg = 8.8
overall = 0.7343 max = 9

F(6,211) = 125.75
corr(u_i, Xb) = -0.4884 Prob > F = 0.0000

logGHG	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Shareofrenewableenergyingrossfin	-.0161045	.0018437	-8.73	0.000	-.019739	-.0124701
logGDPpercapita	.0090355	.0263009	0.34	0.732	-.0428107	.0608816
logFinalenergyconspc	.7622225	.056204	13.56	0.000	.6514292	.8730158
Energyimportsnet	-.0003055	.0004732	-0.65	0.519	-.0012382	.0006273
Environmentaltaxrevenues	.0195301	.0044536	4.39	0.000	.0107509	.0283094
lnRDpc	.0239702	.021058	1.14	0.256	-.0175409	.0654812
_cons	12.05896	.8032661	15.01	0.000	10.4755	13.64241
sigma_u	.1953886					
sigma_e	.03733671					
rho	.9647712 (fraction of variance due to u_i)					

F test that all u_i=0: F(27, 211) = 157.40 Prob > F = 0.0000

Appendix D. Random effects model

xtreg logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc, re

```
Random-effects GLS regression                 Number of obs      =       245
Group variable: V2                            Number of groups   =        28

R-sq:  within  = 0.7797                       Obs per group: min =         8
       between = 0.7500                                      avg =       8.8
       overall = 0.7451                                      max =         9

Wald chi2(6)       =    811.28
corr(u_i, X)   = 0 (assumed)                  Prob > chi2        =    0.0000

----------------------------------------------------------------------------------------------------
                          logGHG |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------------------+------------------------------------------------------------------
Shareofrenewableenergyingrossfin |  -.0158432   .0015666   -10.11   0.000    -.0189138   -.0127727
                 logGDPpercapita |   .0142543   .0258602     0.55   0.581    -.0364308    .0649394
            logFinalenergyconspc |   .7148678   .0462853    15.44   0.000     .6241503    .8055853
                Energyimportsnet |  -.0004739   .0004391    -1.08   0.281    -.0013345    .0003868
        Environmentaltaxrevenues |   .0187012   .0043516     4.30   0.000     .0101723    .0272302
                          lnRDpc |   .0088547   .0199405     0.44   0.657    -.0302281    .0479374
                           _cons |   11.48646   .6718489    17.10   0.000     10.16966    12.80325
---------------------------------+------------------------------------------------------------------
                         sigma_u |  .17681697
                         sigma_e |  .03733671
                             rho |  .95731465   (fraction of variance due to u_i)
----------------------------------------------------------------------------------------------------
```

Appendix E. Fixed or Random: Hausman test

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe	re	Difference	S.E.
Shareofren~n	-.0866139	-.0956069	.008993	.0069411
GDPpercapita	7.47e-06	-1.09e-06	8.55e-06	1.94e-06
Finalenerg~c	3807792	3333173	474618.7	102645.2
Energyimpo~t	-.0070756	-.0087364	.0016609	.0016465
Environmen~s	.0819049	.0667558	.0151491	.0037272
Totalintra~e	-.0014851	-.0016656	.0001805	.0001626

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 21.38

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)

Appendix F. Modified Wald test for group wise heteroskedasticity in fixed effect regression model

xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (28) = 12478.38
Prob>chi2 = 0.0000

Appendix G. Wooldridge test for autocorrelation in panel data and contemporaneous correlation

xtserial logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F(1, 27) = 9.117
Prob > F = 0.0055

xtcsd, pesaran abs

Pesaran's test of cross sectional independence = 5.082, Pr = 0.0000

Average absolute value of the off-diagonal elements = 0.383

Appendix I. Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

xtpcse logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu lnRDpc i.V2 yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr8 ,
> correlation(psar1)

Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

Group variable:	V2	Number of obs =	245
Time variable:	Year	Number of groups =	28
Panels:	correlated (unbalanced)	Obs per group: min =	8
Autocorrelation:	panel-specific AR(1)	avg =	8.75
Sigma computed by casewise selection		max =	9
Estimated covariances =	406	R-squared =	0.9989
Estimated autocorrelations =	28	Wald chi2(37) =	3.48e+07
Estimated coefficients =	42	Prob > chi2 =	0.0000

logGHG	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
Shareofrenewableenergyingrossfin	-.0065335	.0023875	-2.74	0.006	-.0112129	-.001854
logGDPpercapita	.1150314	.043428	2.65	0.008	.029914	.2001487
logFinalenergyconspc	.5259319	.0546871	9.62	0.000	.4187473	.6331166
Energyimportsnet	.0001125	.0003699	0.30	0.761	-.0006124	.0008375
Environmentaltaxrevenues	.013726	.004358	3.15	0.002	.0051845	.0222675
lnRDpc	.0370926	.0177725	2.09	0.037	.0022591	.0719262
V2						
2	.4907105	.0779221	6.30	0.000	.337986	.6434349
3	.4283544	.0356264	12.02	0.000	.358528	.4981809
4	.0378084	.0831399	0.45	0.649	-.1251429	.2007597
5	.1188218	.0446177	2.66	0.008	.0313727	.2062709
6	.6413963	.0656668	9.77	0.000	.5126917	.7701009
7	.2299762	.0262357	8.77	0.000	.1785552	.2813971
8	.3665325	.0357463	10.25	0.000	.296471	.4365941
9	.0258371	.038394	0.67	0.501	-.0494138	.101088
10	-.1549016	.0320777	-4.83	0.000	-.2177727	-.0920305
11	.0842919	.0517657	1.63	0.103	-.0171669	.1857508
12	-.0235632	.0285629	-0.82	0.409	-.0795454	.032419
13	.2920034	.0369453	7.90	0.000	.2195919	.3644148
14	-.153096	.0791457	-1.93	0.053	-.3082188	.0020267
15	.1909895	.0608811	3.14	0.002	.0716647	.3103142
16	.0640237	.0609179	1.05	0.293	-.0553733	.1834207
17	.0270056	.0490896	0.55	0.582	-.0692082	.1232194
18	.1725299	.0610776	2.82	0.005	.0528201	.2922398
19	-.0337216	.0412931	-0.82	0.414	-.1146545	.0472113
20	-.0310861	.0632167	-0.49	0.623	-.1549887	.0928164
21	.4778765	.0536711	8.90	0.000	.3726831	.5830699

22	.0379574	.0517717	0.73	0.463	-.0635133	.1394281
23	.3181498	.0778952	4.08	0.000	.165478	.4708216
24	.0944425	.0407352	2.32	0.020	.014603	.174282
25	.133413	.0432418	3.09	0.002	.0486606	.2181655
26	.0319697	.0766032	0.42	0.676	-.1181698	.1821092
27	-.3869375	.1093717	-3.54	0.000	-.6013021	-.1725728
28	-.0117068	.0353519	-0.33	0.741	-.0809953	.0575817
yr1	.1329009	.0221926	5.99	0.000	.0894041	.1763976
yr2	.1156302	.0195641	5.91	0.000	.0772853	.1539751
yr3	.1043435	.017206	6.06	0.000	.0706205	.1380665
yr4	.0891553	.0128434	6.94	0.000	.0639827	.1143278
yr5	.0482333	.0116764	4.13	0.000	.025348	.0711186
yr6	.0218711	.0071951	3.04	0.002	.0077689	.0359732
yr7	.0256442	.0072902	3.52	0.000	.0113558	.0399327
yr8	.0056143	.0057319	0.98	0.327	-.0056199	.0168486
_cons	7.555499	.9118419	8.29	0.000	5.768322	9.342676

rhos = .5456632 .7394594 .3775929 -.0249345 .9237336 ... .2436367

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xtpcse logGHG Shareofrenewableenergyingrossfin logGDPpercapita logFinalenergyconspc Energyimportsnet Environmentaltaxrevenu i.V2 yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr8 ,correl
> ation(psar1)

Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

Group variable: V2		Number of obs =	245
Time variable: Year		Number of groups =	28
Panels: correlated (unbalanced)		Obs per group: min =	8
Autocorrelation: panel-specific AR(1)		avg =	8.75
Sigma computed by casewise selection		max =	9
Estimated covariances =	406	R-squared =	0.9988
Estimated autocorrelations =	28	Wald chi2(36) =	6.15e+07
Estimated coefficients =	41	Prob > chi2 =	0.0000

logGHG	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
Shareofrenewableenergyingrossfin	-.0060738	.0024488	-2.48	0.013	-.0108734	-.0012743
logGDPpercapita	.162475	.0456949	3.56	0.000	.0729147	.2520354
logFinalenergyconspc	.5255167	.054589	9.63	0.000	.4185241	.6325092
Energyimportsnet	.000028	.0003929	0.07	0.943	-.0007421	.0007981
Environmentaltaxrevenues	.0130497	.0043004	3.03	0.002	.0046211	.0214783
V2						
2	.4579725	.0809565	5.66	0.000	.2993008	.6166443
3	.4189787	.0381105	10.99	0.000	.3442835	.4936739
4	.0329307	.0870307	0.38	0.705	-.1376464	.2035078
5	.1264639	.0435164	2.91	0.004	.0411732	.2117546

6	.6284085	.0701552	8.96	0.000	.4909068	.7659102
7	.2178091	.0274805	7.93	0.000	.1639483	.2716699
8	.3263547	.0357745	9.12	0.000	.256238	.3964715
9	.0081905	.0392525	0.21	0.835	-.068743	.085124
10	-.1573142	.0320447	-4.91	0.000	-.2201207	-.0945078
11	.0630986	.0539049	1.17	0.242	-.0425531	.1687503
12	-.042845	.0288393	-1.49	0.137	-.0993689	.0136789
13	.2470757	.0298865	8.27	0.000	.1884992	.3056522
14	-.1979084	.0788728	-2.51	0.012	-.3524962	-.0433206
15	.1651467	.0634161	2.60	0.009	.0408535	.28944
16	.0509669	.0604709	0.84	0.399	-.067554	.1694877
17	.0146105	.0519033	0.28	0.778	-.0871181	.1163392
18	.1440786	.0627605	2.30	0.022	.0210702	.267087
19	-.0396929	.0433634	-0.92	0.360	-.1246835	.0452978
20	-.0333745	.0645864	-0.52	0.605	-.1599615	.0932125
21	.4463747	.0569692	7.84	0.000	.3347173	.5580322
22	.0189961	.0532053	0.36	0.721	-.0852844	.1232766
23	.2735716	.0827006	3.31	0.001	.1114815	.4356617
24	.0940834	.0420957	2.23	0.025	.0115774	.1765894
25	.090828	.0415799	2.18	0.029	.0093329	.172323
26	.039652	.0781465	0.51	0.612	-.1135123	.1928162
27	-.3902752	.1123245	-3.47	0.001	-.6104272	-.1701233
28	-.0200838	.0371237	-0.54	0.589	-.0928449	.0526773
yr1	.1311082	.0227108	5.77	0.000	.0865959	.1756206
yr2	.1133709	.0197261	5.75	0.000	.0747085	.1520334
yr3	.1021698	.0171858	5.94	0.000	.0684862	.1358534
yr4	.0821859	.0115632	7.11	0.000	.0595224	.1048495
yr5	.0393352	.0100628	3.91	0.000	.0196126	.0590579
yr6	.0159728	.0063759	2.51	0.012	.0034762	.0284694
yr7	.0234848	.0067538	3.48	0.001	.0102477	.0367219
yr8	.0020436	.0056224	0.36	0.716	-.008976	.0130633
_cons	7.295329	.9566076	7.63	0.000	5.420413	9.170246

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rhos = .5461893 .7399224 .4189768 -.0142663 .9243013 ... .3001539

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xtpcse logGHG Shareofrenewableenergyingrossfin logGDPpercapita Energyimportsnet Environmentaltaxrevenu lnRDpc i.V2 yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr8 ,correlation(psar1)

Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

Group variable:	V2	Number of obs =	245
Time variable:	Year	Number of groups =	28
Panels:	correlated (unbalanced)	Obs per group: min =	8
Autocorrelation:	panel-specific AR(1)	avg =	8.75
Sigma computed by casewise selection		max =	9
Estimated covariances =	406	R-squared =	0.9984
Estimated autocorrelations =	28	Wald chi2(36) =	1.22e+07
Estimated coefficients =	41	Prob > chi2 =	0.0000

logGHG	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf. Interval]	
Shareofrenewableenergyingrossfin	-.0099921	.0026064	-3.83	0.000	-.0151006	-.0048836
logGDPpercapita	.2539004	.0475912	5.34	0.000	.1606233	.3471774
Energyimportsnet	.0004526	.0004286	1.06	0.291	-.0003874	.0012927
Environmentaltaxrevenues	.0130223	.0044873	2.90	0.004	.0042274	.0218173
lnRDpc	.0498352	.0205145	2.43	0.015	.0096275	.0900429
V2						
2	.327259	.0823805	3.97	0.000	.1657961	.4887219
3	.4330588	.0398535	10.87	0.000	.3549474	.5111702
4	-.0141448	.0836481	-0.17	0.866	-.178092	.1498024
5	.0244678	.0689612	0.35	0.723	-.1106938	.1596294
6	.6622909	.068152	9.72	0.000	.5287154	.7958664
7	.100269	.0225886	4.44	0.000	.0559961	.1445419
8	.1543334	.0339026	4.55	0.000	.0878854	.2207813
9	-.1557808	.0449504	-3.47	0.001	-.243882	-.0676796
10	-.2888264	.0249921	-11.56	0.000	-.33781	-.2398427
11	-.1160467	.0516848	-2.25	0.025	-.217347	-.0147464
12	-.2066159	.0232889	-8.87	0.000	-.2522613	-.1609706
13	.202721	.0442217	4.58	0.000	.1160481	.2893939
14	-.134913	.0898972	-1.50	0.133	-.3111083	.0412824
15	.0278052	.0666437	0.42	0.677	-.1028141	.1584245
16	.4415319	.0414891	10.64	0.000	.3602147	.5228491
17	-.1320766	.0505481	-2.61	0.009	-.2311491	-.033004
18	-.3115563	.050394	-6.18	0.000	-.4103267	-.212786
19	-.0632353	.0431262	-1.47	0.143	-.1477612	.0212905
20	.0376132	.0675112	0.56	0.577	-.0947064	.1699328
21	.3547671	.0586262	6.05	0.000	.2398618	.4696723
22	-.139901	.0516758	-2.71	0.007	-.2411838	-.0386182
23	.1203438	.08246	1.46	0.144	-.0412748	.2819625
24	.0832011	.0410285	2.03	0.043	.0027866	.1636155
25	.0681494	.0506433	1.35	0.178	-.0311097	.1674085
26	.3058134	.0791585	3.86	0.000	.1506656	.4609612
27	-.231117	.1165273	-1.98	0.047	-.4595063	-.0027276
28	-.181313	.0279357	-6.49	0.000	-.236066	-.12656
yr1	.2086542	.0219558	9.50	0.000	.1656217	.2516868
yr2	.1847181	.0194658	9.49	0.000	.1465659	.2228703
yr3	.1644332	.0169425	9.71	0.000	.1312265	.1976399
yr4	.1230032	.013072	9.41	0.000	.0973825	.1486238
yr5	.0691159	.0121094	5.71	0.000	.0453819	.0928499
yr6	.0316243	.0083751	3.78	0.000	.0152094	.0480392
yr7	.0581894	.0072355	8.04	0.000	.0440081	.0723707
yr8	.0079647	.0071872	1.11	0.268	-.0061219	.0220513
_cons	-.6755003	.4924377	-1.37	0.170	-1.640661	.28966

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                  rhos =  .3431127 -.0590941  .5143463  .0701843   .971911 ...  .3175796
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xtpcse    logGHG   Shareofrenewableenergyingrossfin   logGDPpercapita          logFinalenergyconspc
Energyimportsnet Environmentaltaxrevenu    i.V2 yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr8 ,  corre
> lation(psar1)

Prais-Winsten regression, correlated panels corrected standard errors (PCSEs)

Group variable:   V2                            Number of obs      =       245
Time variable:    Year                          Number of groups   =        28
Panels:           correlated (unbalanced)       Obs per group: min =         8
Autocorrelation:  panel-specific AR(1)                         avg =      8.75
Sigma computed by casewise selection                           max =         9
Estimated covariances      =       406          R-squared          =    0.9988
Estimated autocorrelations =        28          Wald chi2(36)      =  6.15e+07
Estimated coefficients     =        41          Prob > chi2        =    0.0000


------------------------------------------------------------------------------
                     |           Panel-corrected
              logGHG |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------------+--------------------------------------------------------
Shareofrenewableenergyingrossfin |  -.0060738   .0024488    -2.48   0.013    -.0108734   -.0012743
     logGDPpercapita |    .162475   .0456949     3.56   0.000     .0729147    .2520354
logFinalenergyconspc |   .5255167    .054589     9.63   0.000     .4185241    .6325092
    Energyimportsnet |    .000028   .0003929     0.07   0.943    -.0007421    .0007981
Environmentaltaxrevenues |   .0130497   .0043004     3.03   0.002     .0046211    .0214783
                     |
                  V2 |
                  2  |   .4579725   .0809565     5.66   0.000     .2993008    .6166443
                  3  |   .4189787   .0381105    10.99   0.000     .3442835    .4936739
                  4  |   .0329307   .0870307     0.38   0.705    -.1376464    .2035078
                  5  |   .1264639   .0435164     2.91   0.004     .0411732    .2117546
                  6  |   .6284085   .0701552     8.96   0.000     .4909068    .7659102
                  7  |   .2178091   .0274805     7.93   0.000     .1639483    .2716699
                  8  |   .3263547   .0357745     9.12   0.000      .256238    .3964715
                  9  |   .0081905   .0392525     0.21   0.835     -.068743     .085124
                 10  |  -.1573142   .0320447    -4.91   0.000    -.2201207   -.0945078
                 11  |   .0630986   .0539049     1.17   0.242    -.0425531    .1687503
                 12  |   -.042845   .0288393    -1.49   0.137    -.0993689    .0136789
                 13  |   .2470757   .0298865     8.27   0.000     .1884992    .3056522
                 14  |  -.1979084   .0788728    -2.51   0.012    -.3524962   -.0433206
                 15  |   .1651467   .0634161     2.60   0.009     .0408535      .28944
                 16  |   .0509669   .0604709     0.84   0.399     -.067554    .1694877
                 17  |   .0146105   .0519033     0.28   0.778    -.0871181    .1163392
                 18  |   .1440786   .0627605     2.30   0.022     .0210702     .267087
                 19  |  -.0396929   .0433634    -0.92   0.360    -.1246835    .0452978
                 20  |  -.0333745   .0645864    -0.52   0.605    -.1599615    .0932125
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21	.4463747	.0569692	7.84	0.000	.3347173	.5580322
22	.0189961	.0532053	0.36	0.721	-.0852844	.1232766
23	.2735716	.0827006	3.31	0.001	.1114815	.4356617
24	.0940834	.0420957	2.23	0.025	.0115774	.1765894
25	.090828	.0415799	2.18	0.029	.0093329	.172323
26	.039652	.0781465	0.51	0.612	-.1135123	.1928162
27	-.3902752	.1123245	-3.47	0.001	-.6104272	-.1701233
28	-.0200838	.0371237	-0.54	0.589	-.0928449	.0526773
yr1	.1311082	.0227108	5.77	0.000	.0865959	.1756206
yr2	.1133709	.0197261	5.75	0.000	.0747085	.1520334
yr3	.1021698	.0171858	5.94	0.000	.0684862	.1358534
yr4	.0821859	.0115632	7.11	0.000	.0595224	.1048495
yr5	.0393352	.0100628	3.91	0.000	.0196126	.0590579
yr6	.0159728	.0063759	2.51	0.012	.0034762	.0284694
yr7	.0234848	.0067538	3.48	0.001	.0102477	.0367219
yr8	.0020436	.0056224	0.36	0.716	-.008976	.0130633
_cons	7.295329	.9566076	7.63	0.000	5.420413	9.170246

rhos = .5461893 .7399224 .4189768 -.0142663 .9243013 ... .3001539

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