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Structure and environmental impact of global energy consumption

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A R T I C L E I N F O

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This paper presents information on global energy consumption by fuel type (liquid fuels, coal, natural gas, renewables and nuclear) and sectors (buildings, industrial, transportation and electricity), and environmental impact of global energy consumption (SO_x, NO_x and CO_2 emissions). There is a strong relationship between energy consumption and economic growth. The Global Financial Crisis has affected the global economic growth violently. The governments have recently adopted some effective measures to fight against the Global Financial Crisis. The structure of energy consumption and the conditions of SO_x, NO_x, and CO_2 emissions affect the global changes (acid rain and greenhouse effect). Today, considerable effort is being devoted to reduce CO_2 emissions because of the Kyoto Protocol on climate change. This publication presents multidisciplinary perspectives on the interrelated topics of energy consumption, energy security and energy policy. Additionally, the present study examines the relationship between energy consumption and greenhouse gas emission.

Contents

1. Introduction

Energy is essential for economic and social development and improved quality of life in all countries [1]. Energy is defined as the ability to do work and it can be found in different forms such as

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chemical, thermal, electricity, mechanical, gravitational, nuclear, radiant, sound, and motion. Energy can be stored, converted and/or amplified depending on the application. Energy sources can be fossil (petroleum, coal, betumes, natural gas, shale oil, etc.), renewable (alternative) (biomass, hydro, wind, solar, geothermal, marine, hydrogen, etc.) and fissile (uranium, thorium, etc.) [2].

Energy is a special topic because it is a key input to almost all other consumptions and production processes. Energy is therefore a crucial parameter controlling growth and determining many aspects of human activity in general [3].

The increases in economical growth of the developing countries in the last decades have caused rapid increase in energy consumption. According to Kaygusuz and Bilgen, this trend is expected to increase in the near future [4]. Energy use is very important for people's survival and development. The increases in energy consumption have usually affected to improve life styles [5]. Consumption is a key lever to achieve more sustainable development. Unsustainable consumption is a major cause of global environmental deterioration, including overexploitation of renewable resources and pollution caused by fossil fuels [6].

Li et al. have recognized a strong relationship between energy consumption and economic growth. Energy demands of most countries declined during the economic depression which caused a worldwide economic crisis between 2008 and 2009 [7]. The Global Financial Crisis has been called the most serious financial crisis since the Great Depression. This crisis has caused a significant decline in economic activity [8].

The by-products of energy production, distribution, and consumption define the single largest environmental loading of society when taken together. Awareness of this loading has recently evolved from a focus on point sources of pollution with point effects to distributed sources with distributed effects [9].

Major problems in global economy are energy and environmental security. Fossil fuels are confined to a few regions of the world. The continuity of supply is governed by dynamics of political, economical and ecological factors. Increased growth and demand for the welfare of developed and developing countries is creating a higher pressure on energy resources. A large part of new consumers in developing countries have already started purchasing high power so as to be able to access commodity and energy markets worldwide, thus boosting the energy consumption and competition for all kinds of resources [10].

A projection of the future energy consumption is a vital input to analyze economic, energy, and environmental policies. An outlook on the future energy consumption helps us in deciding on future energy investment. It is very important that the prediction of future energy consumption be as accurate as possible. Since there is no information about the future of industrial structure and level of energy efficiency in each industry for a country, we may start with the assumption that it will follow the usual trend observed in the past. This is exactly how we have made our projections on the future energy intensity and consumption: the projections are based on their historical trend identified by the experience model [11].

Energy source is the basic element of socio-economic development. Energy supply and security has become the major issues of the development of human society and global political and economic pattern. Countries in the world have natural resource endowment conditions and different economic development level. Thus, energy supply and consumption of different countries also have some geographical differences [12].

2. Structure of global energy consumption

In view of the new millennium challenges for the modern faster socio-economic upgradation and adoption of new lifestyle, the industrial development seems to be at a very high demand as revealed from the on-going energy consumption and its anticipated energy requirements as a whole in developed countries in general and in developing countries of the world in particular. It appears that energy demand will keep increasing but the conventional sources for generating electricity will deplete with time or may become environmentally hazardous enhancing global warming. Due to deplete of coal, petroleum and natural gas reserves and/or associated world politics, the nuclear energy source is also being considered as one of the alternate by the developing countries but because of its hazardous issues, relatively higher expenses and technological monopolies, it is not approachable for most of the countries of the world. Anticipating this decline, renewables are being given preferences as alternate and long-lasting sources of energy generation. This rational approach is environmental friendly and free from the danger of producing pollution and health hazards of the people [13].

Though global energy demand and resource consumption are at a slower rate than in recent years, it is projected to increase over the next several decades [14]. The need for energy and fuels is one of the common threads throughout history and related to development criteria for developing countries. It is vital for consumption of energy to be used in a productive manner for sustainable development due to the increase of petroleum prices recently and the limited lifetime of fossil fuels [15]. Most of the global increase comes from developing countries for energy and population. As Lawrence et al., the issues of total energy consumption and carbon emissions are inextricably related to the problem of energy inequality among the countries of the world [16].

The world consumption of energy in 1990 was about 1 billion gigawatts, and now is approaching 10 billion gigawatts. This tenfold increase in one century is the product of a threefold increase in world population and a roughly threefold increase in average per capita use. The increase in per capita energy use is linked to the growth of the world economy [9].

As discussed by Zhang and Conan, the United States maintains a significant volume of demand for energy but its relative consumption share is decreasing over time, from 24.1% in 2010 to 19.8% by 2050. Japan sustains very high demand in oil with a share of 31.5% in the global market in 2010, 27.7% in 2030, and 24.8% in 2050. Global energy consumption is projected to increase significantly, growing from 13.6 billion tons of oil equivalent (t.o.e.) in 2010 to 44.6 billion t.o.e. by 2050. Owing to China's significant and growing role within global energy markets, global coal demand increases from 3.6 billion t.o.e. in 2010 to 12.9 billion t.o.e. in 2050. Global coal energy demand also expands from 26.5% in 2010 to 28.9% in 2050, with gas and electricity representing a contracting share of total demand [17].

10% of the population of the world exploits 90% of fossil fuel resources. Today's energy systems rely heavily on fossil fuel resources diminishing ever faster. The world must prepare for a future without fosil fuels. Sustainable energy consumption has become urgent matter for all countries [18].

World energy consumption increases from 524 quadrillion Btu in 2010 to 630 quadrillion Btu in 2020 and 820 quadrillion Btu in 2040 (Table 1) [19].

2.1. Global energy consumption by fuel type

If all of the carbon present in the fuel is burned to carbon dioxide, all of the hydrogen is burned to water, and all of the sulfur is burned to sulfur dioxidecombustion is complete [20,21]. Saving fuel is the most important measure for the protection of the environment and climate. Development will be shaped by saving resources, decelerating fuel consumption, and supporting technical developments [22].

Globally, in view of different factors such as fast depletion of fuel resources, increasing consumption of fossil fuel, uncertainties with the future availability of fosil fuel, increasing world energy demand, energy and cost saving, increase in pollutants emissions and producing skin diseases and climatic changes (greenhouse, heating Earth), many studies have been directed for investigations on using different sources of energy instead of oil and its derivatives. Among them we can cite natural gas and biofuel [2].

Many governments and business executives around the world have ambitious plans towards changing their energy mix and investment plans. These plans include more renewables and more low-carbon energy. However, the global energy mix is still likely to be dominated by fossil fuels in the foreseeable future [23].

The use of all energy sources increases over the time horizon of the *AEO2014* and *AEO2013* Reference case (Table 2). The importance of energy security, the harmful effects of fosil fuel emissions, and the increase of oil prices support use of nuclear power and renewable energy over the projection. Policies and incentives of governments improve the prospects for non-fossil forms of energy in many countries in the world in the Outlook [24].

2.1.1. Liquid fuels

The liquid is composed of a very complex mixture of oxygenated hydrocarbons determined its composition intrinsically by the rate of reaction and product quenching, and extrinsically by the feed composition [20].

The major source of energy is petroleum, rising from about 38% in 1950 to 45% in 1975, and then declining to about 40% in response to the energy crisis of the 1970s. The transportation sector dependence on gasoline as petroleum fuel. With the downturn in the world economy and a consequent decline in consumption, prices collapsed, but the dependence on imported oil continues as a potential problem. About 40% of the energy consumed in the United States is supplied by petroleum, and that proportion has remained approximately the same since 1950 [14].

The character and the timing of a global peak in oil production are determined by consumption, economics, and technology. Thus, assertive predictions of peak production are nearly untenable because it requires the predictor to have an excellent grasp of these three determinants, even going into the future. Some optimists run a foul even of the physical limits of the known universe, let alone of our Earth. Of course, far short of the limits of the universe, oil and gas extraction are defined by Earthly limits [25].

Table 1
World energy consumption by country grouping, 2010–2040 (quadrillion Btu).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD	**242**	**244**	**255**	**263**	**269**	**276**	**285**	**0.5**
Americas	120	121	126	130	133	137	144	0.6
Europe	82	82	85	89	91	93	95	0.5
Asia	40	41	43	44	45	46	46	0.5
Non-OECD	**282**	**328**	**375**	**418**	**460**	**501**	**535**	**2.2**
Europe and Eurasia	47	50	53	57	61	65	67	1.2
Asia	159	194	230	262	290	317	337	2.5
Middle East	28	33	37	39	43	46	49	1.9
Africa	19	20	22	24	27	31	35	2.1
Central and South America	29	31	33	35	39	42	47	1.6
World	**524**	**572**	**630**	**680**	**729**	**777**	**820**	**1.5**

2.1.2. Coal

Coal is overwhelmingly abundant and more widely distributed in some countries in comparison with oil and natural gas, Therefore, it is important to utilize the coal efficiently and cleanly [26,27].

Consumption of coal in 1950 was 35% of the total. This proportion is almost equal to oil. It declined to about 20% a decade later and has remained at about that proportion since then. Coal currently is used almost exclusively for electric power generation. Consumption of coal has more than doubled since 1950, but during that period coal as an energy source changed from a widely used resource to a single-use fuel for generating electricity. The electric power sector consumed less than 20% of the half-billion tons of coal burned in 1950 and used more than 90% of the billion-plus tons consumed in 2007 [14].

Coal dominates the United States fossil energy endowment and accounts for 48% of domestic electricity generation. Coal is currently the most important fuel for electricity generation. Studies will determine what portion of the resource base is technically and economically recoverable [14].

2.1.3. Natural gas

Natural gas might be considered a very uninteresting, colorless, shapeless and odorless gas in its pure form. Natural gas is combustible, gives off a great deal of energy when burned. It is clean and emits lower levels of pollutants into the air unlike other fossil fuels. From the chemical viewpoint, natural gas consists of a mixture of inorganic gases and saturated hydrocarbons that occurs in gaseous state at environmental temperature and pressure [2].

Consumption of natural gas was almost four times as great in 2007 as it was in 1950 [14]. Some countries have sufficient natural gas reserves. They are in a good position to export this valuable fuel. The ration of proven (or, in some cases, estimated) reserves to the annual total energy consumption can provide such countries

Table 2
Comparison of projections in the AEO2014 and AEO2013 Reference cases, 2011–2040.
Source: Ref. [24].

Energy consumption by fuel (quadrillion Btu)	2011	2012	2025		2040	
			AEO2014	AEO2013	AEO2014	AEO2013
Petroleum and other liquid fuels	36.56	35.87	36.28	36.87	35.35	36.07
Natural gas	24.91	26.20	28.97	27.28	32.32	29.83
Coal	19.62	17.34	19.03	19.35	18.75	20.35
Nuclear/uranium	8.26	8.05	8.15	9.54	8.49	9.44
Hydropower	3.11	2.67	2.84	2.86	2.90	2.92
Biomass	2.60	2.53	3.74	3.82	4.26	4.91
Other renewable energy	1.70	1.97	3.09	2.32	3.89	3.84
Other	0.35	0.39	0.35	0.30	0.35	0.29
Total	**97.11**	**95.02**	**102.45**	**102.34**	**106.31**	**107.64**

with a useful indicator for assessing whether they can initiate or expand exports of natural gas [28].

Natural gas produces lower emissions of carbon dioxide than coal or oil for equivalent amounts of energy supplied. Therefore, it has emerged as a highly desirable fuel. The ratio of proven natural gas of a country reserves to its total energy consumption is a good indicator of its ability to improve its air quality situation or address greenhouse gas reduction targets from domestic natural gas sources [29].

2.1.4. Renewables

Renewable energy sources have been important for humans since the beginning of civilization [30]. Renewables are the fastest growing source of world energy consumption. The increased attention on renewable energy sources can be attributed to a number of factors. The recent concerns over the volatility of oil prices, the dependency on foreign energy sources, and the environmental consequences of carbon emissions are all contributing factors to the current interest in renewable energy sources. Moreover, the emergence of government policies such as renewable energy production tax credits, installation rebates for renewable energy systems, renewable energy portfolio standards, and the establishment of markets for renewable energy certificates have been critical in the promotion of renewable energy as a viable component of the energy portfolio for various countries [31].

Renewable energy sources (except hydropower) continue to offer more potential than actual energy production The role of hydropower in electricity generation has gradually declined, from 30% in 1950 to 15% in 1975 and less than 10% in 2000. However, hydropower remains highly important on a regional basis [14].

Renewable energy is the fastest growing source in electricity generation. Total generation from renewable resources increases by 2.8% annually, and the renewable share of world electricity generation increases from 21% in 2010 to 25% in 2040. About 80 percent of this increase is in hydroelectric and wind power (Table 3) [19].

Table 3
OECD and non-OECD net renewable electricity generation by energy source, 2010–2040 (billion kilowatthours).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD								
Hydroelectric	1338	1412	1497	1574	1661	1749	1841	1.1
Wind	269	531	718	855	903	961	1052	4.7
Geothermal	41	52	68	79	93	104	115	3.5
Solar	32	123	145	165	181	211	253	7.1
Other	263	290	346	373	385	401	426	1.6
Total OECD	**1943**	**2408**	**2774**	**3046**	**3222**	**3426**	**3687**	**2.2**
Non-OECD								
Hydroelectric	2064	2393	2955	3188	3516	3943	4390	2.6
Wind	73	235	418	527	641	733	787	8.3
Geothermal	25	60	65	67	78	91	105	4.9
Solar	1	34	95	124	146	183	199	18.6
Other	69	137	202	270	344	400	432	6.3
Total non-OECD	**2232**	**2859**	**3736**	**4177**	**4725**	**5350**	**5914**	**3.3**
World								
Hydroelectric	3402	3805	4452	4762	5177	5692	6232	2.0
Wind	342	767	1136	1383	1544	1694	1839	5.8
Geothermal	66	112	133	146	171	195	220	4.1
Solar	34	157	240	288	327	394	452	9.1
Other	332	427	549	643	729	800	858	3.2
Total World	**4175**	**5267**	**6509**	**7222**	**7948**	**8775**	**9601**	**2.8**

2.1.5. Nuclear

Nuclear power does not lead to emission of greenhouse gases. In electricity generating plant, replacement of any fossil fuel by a nuclear one will reduce emission of greenhouse gases. Such a reduction of greenhouse gas emissions and the reduction of emission of greenhouse gases by improvement of end use efficiency (loosely called energy conservation) are independent of each other. Both can be partially effective. It is stupid to reject either because it will not do the whole job. If the effect of rising greenhouse gas concentrations is as bad as most scientists fear, both are necessary [29].

Nuclear power has started to become popular in the late 1960s. In the midst of the oil crisis, it was supplying 9% of total electricity generation. Continuation of some construction increased the nuclear share of generation to 20% in 1990 [14]. There were 437 nuclear power reactors in operation at the beginning of 2010. Eleven construction starts were made in 2009. Ten of these constructions are in Asia. In 2009, the United States Nuclear Regulatory Commission approved eight license renewals of 20 years each, bringing the number of approved renewals to 59. License renewals were either granted or being processed in several other countries. The post-2000 trend of license renewals or extensions for many operating reactors continued, especially in the USA [32].

2.2. Global energy consumption sectors

Energy Information Administration's (EIA's) portfolio of data collections includes three surveys of energy-consuming end use sectors: the Commercial Buildings energy Consumption Survey (CBECS), the Residential Energy Consumption Survey (RECS), and the Manufacturing Energy Consumption Survey. Prior to 1994, EIA also conducted a transportation energy use survey, the Residential Transportation Energy Consumption Survey, but budget cuts forced this data collection to be discontinued after 1994 [33].

The demand for energy in areas as varied as industry or transport means that a new paradigm in the way fuels. The need to promote energy security and policy as key themes during the twenty-first century is greater than ever [23].

In the times of globalization, international trade is playing a vital role in shaping the world energy profile by redistributing the energy embodied in industrial products in the economy. The leakage effects associated with indirect energy use at the global scale are overlooked because traditional analyses are usually focusing on direct energy use [34].

2.2.1. Buildings sector (residential and commercial) energy consumption

The buildings sector represents energy use in places where people reside, work, and buy goods and services. The sector excludes industrial facilities used for producing, processing, or assembling goods. In 2010, the buildings sector accounted for more than one-fifth of total worldwide consumption of delivered energy [19].

Many governments have introduced regulations to make buildings more energy-efficient. Policies and research on energy conservation in buildings are geared primarily to saving energy through technical measures relating to the building envelope and the heating and ventilation installations [35]. Energy-saving designs do not always result in the expected energy consumption [36,37].

Energy consumption in housing and building is a key issue for sustainability, primarily because it contributes to the depletion of non-renewable fossil fuels and the production of carbon dioxide (CO_2) and other pollutions. Energy use in houses and other buildings is significant proportion of energy consumption, set to rise with increase in population and the number of associated buildings, notably houses [3].

Buildings are the environment where the majority of us spend most of our lives; they deeply influence many other consumption patterns and are important factor in our life and comfort. The societal function and nature of buildings as they are currently culturally constructed accounts for many of the difficulties in moving towards sustainable consumption and production (SCP), both present and future. Buildings have a long lifetime. This domain is a major target for any structural change in consumption patterns [3].

Energy use in the residential sector is defined as the energy consumed by households, excluding transportation uses. In the residential sector, energy is used for equipment and to provide heating, cooling, lighting, water heating, and other household demands. All of energy consumption, income, and energy prices affect the way energy consumed in the residential sector. However, residential energy use is affected by factors such as location, building and household characteristics, weather, type and efficiency of equipment, energy access, availability of energy sources, and energy-related policies. As a result, the type and amount of energy use by households can vary widely within and across regions and countries [19]. Residential buildings have continuously improved in efficiency. Though materials with better thermal properties and more efficient systems have lowered energy consumption for space heating in recent decades, substantial differences in energy consumption are still being observed in similar dwellings [35,38,39]. World residential delivered energy consumption increases by 57% from 2010 to 2040 (Table 4) [19].

Energy consumption in the commercial sector focuses on heating and cooling systems, lights, water heaters, and other equipment in the buildings located businesses, institutions, and other organizations. Schools, retail stores, restaurants, hotels, hospitals, office buildings, and leisure and recreational facilities can be given as examples of commercial sector buildings. The commercial sector included some nonbuilding energy use contributes to such public services as traffic lights and water and sewer systems. Total world delivered commercial sector energy consumption grows at an average annual rate of 1.8% from 2010 to 2040, making it the fastest-growing demand sector (Table 5) [19].

In Europe the built environment consumes 40% of the produced energy. A large proportion of this energy is consumed in residential buildings. Households account for about 30% of the total building-related energy consumption in OECD countries [40]. As around 30–57% of the energy consumed by households is spent on space and domestic water heating, conservation in this area is a matter of vital importance [35]. In a context marked by a growing effort to create sustainable development strategies, much of the research focuses on energy related issues in the built environment [41].

Table 4
Residential sector delivered energy consumption by region, 2010–2040 (quadrillion Btu).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD	**28.2**	**28.1**	**29.0**	**29.9**	**30.8**	**31.3**	**32.0**	**0.4**
Americas	13.2	12.8	12.9	13.2	13.5	13.9	14.2	0.3
Europe	11.7	11.9	12.5	13.1	13.5	13.7	13.9	0.6
Asia	3.3	3.4	3.5	3.7	3.8	3.8	3.9	0.5
Non-OECD	**23.9**	**27.0**	**30.8**	**35.1**	**40.0**	**45.0**	**49.8**	**2.5**
Europe and Eurasia	6.3	6.3	6.7	7.1	7.7	8.1	8.6	1.0
Asia	10.6	12.8	15.6	18.7	22.2	25.9	29.6	3.5
Middle East	3.4	3.9	4.2	4.4	4.6	4.7	4.8	1.2
Africa	1.6	1.7	1.9	2.2	2.5	2.8	3.2	2.4
Central and South America	2.0	2.3	2.4	2.7	3.0	3.4	3.7	2.1
World	**52.0**	**55.1**	**59.8**	**65.0**	**70.8**	**76.3**	**81.8**	**1.5**

Table 5
Commercial sector delivered energy consumption by region, 2010–2040 (quadrillion Btu).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD	**20.2**	**20.9**	**22.0**	**23.2**	**24.4**	**25.5**	**26.5**	**0.9**
Americas	9.8	10.1	10.5	10.9	11.5	12.0	12.6	0.8
Europe	6.5	6.9	7.4	7.8	8.3	8.6	9.0	1.1
Asia	3.9	3.9	4.2	4.4	4.6	4.8	5.0	0.8
Non-OECD	**8.8**	**9.9**	**11.7**	**13.9**	**16.5**	**19.4**	**22.5**	**3.2**
Europe and Eurasia	2.2	2.3	2.5	2.8	3.1	3.5	3.8	1.8
Asia	4.2	4.9	6.0	7.4	9.1	11.0	13.1	3.9
Middle East	1.0	1.1	1.3	1.5	1.7	1.9	2.0	2.4
Africa	0.4	0.5	0.6	0.7	0.8	1.0	1.2	3.5
Central and South America	1.0	1.1	1.3	1.5	1.8	2.0	2.4	3.1
World	**28.9**	**30.8**	**33.6**	**37.1**	**40.9**	**44.8**	**49.0**	**1.8**

2.2.2. Industrial sector energy consumption

Industrial promotion is a major priority for the governments of many developing countries. Industrial development can make significant beneficial contributions to a country's overall economic development by providing jobs, promoting socio-economic infrastructure and so on. However, by its very nature, industrial development can also have profound impact on the environment. All industrial require use of natural resources, many of which are limited, such as water, and so can directly affect local ecosystems. The conversion of natural resources to finished or semi-finished products results in residues that are often discharged as wastes. These wastes in solid, liquid and gaseous forms can be detrimental to the quality of life by adversely affecting land, water and air resources [42].

In Industrial and Post-Industrial Nations like those in North America and in Europe, or in Industrializing Nations like China, India, and Brazil, there are universally recognizable economic sectors that consume energy for productive purposes. Prior to the first extensive use of fossil fuels, firewood and animal power provided most of the energy input needed to satisfy society. As populations grew and advanced economically and socially, it became apparent that more intensive and more portable energy sources would be needed to support wide-scale mechanization. Wind and water power, and charcoal answered that challenge initially, but it was coal that permitted tremendous expansion of industry. The fact that coal had been accumulated and intensified over millions of years made it a source that dwarfed the biomass fuels, where the forests only represented a few hundred years of accumulation [25].

With new products and increasing affluence, the composition of production is changing such that industrial energy and materials consumption are growing more slowly than the economy. Technological progress tends to reduce the overall energy and materials requirements for each industrial process. This relatively rosy scenario faces serious difficulties, however; industrial decision makers strongly discount future expenditures for energy for a variety of reasons. In addition, many slow-growing heavy industries may not have the capital and technical capabilities to invest in the best new production processes. For these reasons it is important to develop public policies to encourage the development and dissemination of more-efficient process technologies, and to assist energy-intensive industries to modernize, for example through utility demand-side management progams [29].

It is very important to improve energy efficiency in all industrial sectors. The overall aim is to decrease the greenhouse gas emissions, ensure the energy security and improve the industrial output and competitiveness. In the end part of the production chain, the conscious customers in the industrialized countries have woken up by the threats of global warming, changed their consuming habits and started to demand green and sustainable products and services. The uncertainty about global fossil energy reserves and their availability in the long run is increasing the awareness for the development of clean and renewable energy resources and optimized energy use to prevent waste [43].

There are cases of energy consumption that is identified as industrial consumption but not clarified as the consumption of a specific disaggregated industrial sector. In such cases, the energy consumption is accounted for under the non-specified industry classification [44].

Energy consumption worldwide by the industrial sector is expected to grow from 200 quadrillion Btu in 2010 to 307 quadrillion Btu in 2040, increasing by an average of 1.4% per year. Most of the long-term growth in industrial sector delivered energy consumption occurs in the non-OECD countries (Table 6) [19].

2.2.3. *Transportation sector energy consumption*

Since the transportation sector is so heavily dependent on petroleum Table 7 present a more detailed breakdown of the various types of petroleum used. Most of the petroleum consumed in the transportation sector is motor gasoline. In 1950, it was 71% of total sector petroleum consumption. It has been about 65% in recent years [14].

The higher demand for transportation could be fulfilled with the assistance of new technologies, new materials and highly intelligent hardware and software systems. Additionally, navigation and active communication systems can optimally and safely regulate the increasing traffic. Vehicles, airplanes and ships are becoming more and more efficient, i.e., lighter and more intelligent, with improved aerodynamics, optimized design, and higher performance. Both the population of the world and the demand for transportation have been continuously increasing. Transport has become the basic foundation of the economy in all countries. In the course of this process, the environment and the climate have been changing in a remarkable way and in turn have influenced transport. The number of motor vehicles, ships, and airplanes is rapidly rising, especially in fast developing countries. Parallel to this, the amount of oil products consumed and the mass of pollutants emitted are intensively increasing. Transport burns most of the petroleum of the world and emits the most air pollution, including unburned hydrocarbons, carbon monoxide, nitrous oxides, and particles. It is the fastest growing consumption and emission sector on Earth. This leads to significant environmental and health problems especially in large cities and is a major contributor to global warming because of emissions of carbon dioxide [22].

Modifications in energy demand or supply will cause indirect impacts in many other domains. For example, raised prices for energy tend to make activities more local through rising the costs of transportation [3].

A new sustainable path is required, which focuses on reasonable mass transport at a reasonable price, short travel times with

Table 7
Transportation use of petroleum, 1950–2007 (million barrels per day).
Source: Ref. [14].

	Aviation	Diesel Fuel	Gasoline	Other	Total
1950	0.1	0.2	2.4	0.6	3.4
1955	0.3	0.4	3.2	0.5	4.5
1960	0.5	0.4	3.7	0.4	5.1
1965	0.7	0.5	4.4	0.4	6.0
1970	1.0	0.7	5.6	0.4	7.8
1975	1.0	1.0	6.5	0.4	9.0
1980	1.1	1.3	6.4	0.7	9.5
1985	1.2	1.5	6.7	0.4	9.8
1990	1.5	1.7	7.1	0.5	10.9
1995	1.5	2.0	7.7	0.5	11.7
2000	1.7	2.4	8.4	0.5	13.0
2005	1.7	2.9	8.9	0.5	14.0
2006	1.7	3.0	9.0	0.5	14.2
2007	1.6	3.0	9.1	0.5	14.3

Table 6
World industrial sector delivered energy consumption by region and energy source, 2010–2040 (quadrillion Btu).
Source: Ref. [19].

Region	2010	2015	2020	2025	2035	2040	Average annual percent change	
							1990–2010	2010–2040
OECD	**71.9**	**72.9**	**77.5**	**80.4**	**82.2**	**84.4**	**87.1**	**0.6**
Petroleum and other liquids[a]	27.4	27.5	29.3	30.3	31.0	31.7	32.6	0.6
Natural gas	19.4	20.2	21.7	22.7	23.5	24.3	25.2	0.9
Coal	8.7	8.7	9.0	9.2	9.2	9.2	9.2	0.2
Electricity	11.0	11.3	12.0	12.4	12.6	12.9	13.2	0.6
Renewables[b]	5.3	5.2	5.5	5.7	6.0	6.3	7.0	0.9
Non-OECD	**128.1**	**148.5**	**169.2**	**186.0**	**201.3**	**213.3**	**219.8**	**1.8**
Petroleum and other liquids[a]	29.8	34.1	37.1	39.8	43.2	46.5	49.5	1.7
Natural gas	26.1	28.7	32.6	36.3	40.0	43.6	46.6	2.0
Coal	44.2	53.0	61.1	67.0	71.0	72.6	70.4	1.6
Electricity	18.2	22.9	27.4	30.9	33.9	36.1	36.8	2.4
Renewables[b]	9.9	9.8	10.9	12.0	13.3	14.8	16.6	1.7
World	**200.0**	**221.4**	**246.7**	**266.4**	**283.5**	**297.9**	**306.9**	**1.4**
Petroleum and other liquids[a]	57.2	61.6	66.4	70.1	74.2	78.2	82.1	1.2
Natural gas	45.5	48.8	54.3	59.0	63.4	67.8	71.7	1.5
Coal	52.9	61.7	70.1	76.2	80.2	81.9	79.6	1.4
Electricity	29.2	34.2	39.4	43.3	46.5	49.0	50.0	1.8
Renewables[b]	15.2	15.0	16.5	17.7	19.2	21.1	23.5	1.5

[a] *Other liquids* here refers to natural gas liquids and those derived from the Fischer–Tropsch process.
[b] Includes biomass used for combined heat and power operations as well as biomass for process heat.

optimal connections, positive impacts in safety, and improvements in sustainability. Good examples are needed worldwide. Transportation could be improved with the introduction of carbon taxes, higher fuel efficiency standards and the use of new kinds of fuels. It is not enough to produce biogenic and synthetic fuels, although they can be optimally used in road vehicles, airplanes and ships, because they have their own additional problems. On the one side, their utilization lowers the consumption of fossil fuels, but on the other side, their exaggerated use could contribute to the destruction of agriculture and the landscape [22].

The higher comfort level and safety of new vehicles, airplanes and ships also contributes to more sustainability in transportation. Regarding fuel consumption and emission characteristics, regulations have been intensively expanded in the last 20 years. Energy use and emissions vary greatly between several modes of transportation. Electrification and energy efficiency of transport must be increased in the next decades. However, the introduction of new technology will not happen suddenly but only gradually [22].

Less than optimal measures to order intensive fuel saving could cause major economic losses. Fuel substitution in transportation has high investment costs in comparison to other sectors of the economy. Therefore, besides technology, a sustainable strategy requires the increased use of renewable energy resources, worldwide intelligent navigation measures, common international regulations, and voluntary agreements between governments, civil, and international organizations limiting fuel consumption and exhaust gas emissions. Transportation will grow very intensively over the next few decades in comparison to other sectors of the economy, especially in the rapidly developing countries [22].

Transportation accounts for about 20% of the global primary energy consumption and about 18% of the total anthropogenic greenhouse gas emissions. Road transport accounts for 72% of the total energy use within the world's transportation sector and for more than 80% of the total CO_2 emissions. In the period 1990–2005, the energy requirements for transportation increased 37%, making transportation the fastest growing energy sector [45].

World energy consumption in the transportation sector increases by an average of 1.1% per year (Table 8). The most important components of transportation sector energy used throughout the projection are petroleum and other liquid fuels. Most of the growth in transportation energy use occurs in the non-OECD nations. It increases by an average of 2.2% per year from 2010 to 2040 (Table 8) [19].

2.2.4. Electricity

Electricity is essential to power industrialized and industrializing economies. It affects nearly every aspect of daily modern living, and indeed is an essential element to the industrial, residential, and commercial sectors of society. It is almost unimaginable to lack access to electricity for heating, cooling, lighting, working on computers, and watching TV shows. Electricity is the “most convenient, most flexible, and most useful of energies.” Flip a light switch and a whole room can be illuminated. Plug in an air conditioner, turn it on, and a hot, sweltering day becomes manageable for working, playing or even sleeping [25].

Coal was used to generate about half the rapidly increasing amount of electricity consumed. Petroleum became briefly important as a source of power generation in the late 1960s because it resulted in lower emissions of air pollutants, and consumption continued in the 1970s despite the price surge because natural gas was in short supply. By the 1980s, however, oil consumption by utilities dropped sharply, and in 2007 only 1.2% of power generation was oil-fired. Natural gas generation has a more complicated history. Consumption by the electric power industry increased gradually as access by pipeline became more widespread. Nuclear power started coming on line in significant amounts in the late 1960s, and 1975, in the midst of the oil crisis, was supplying 9% of total generation. Construction of major hydroelectric projects has also essentially ceased, and hydropower's share of electricity generation has gradually declined from 30% in 1950 to 15% in 1975 and less than 10% in 2000. However, hydropower remains highly important on a regional basis. Sources of power generation vary greatly by region [14].

World net electricity generation increases by 93% from 20.2 trillion kilowatthours in 2010 to 39.0 trillion kilowatthours in 2040 (Table 9). Electricity is the world's fastest-growing form of delivered energy. World electricity delivered to end users rises by 2.2% per year from 2010 to 2040 [19].

2.2.5. Energy losses in sectors

Losses occur when the efficiency of a device or process deviates from the efficiency that would occur if the device or process were ideal. The value of a loss is a measure of this deviation from ideality.

Energy losses are not necessarily indicative of a deviation from ideality. For instance, some processes lose heat to the surroundings, but if this heat is emitted at the temperature of the surroundings the loss does not lead to an irreversibility. Conversely, some processes have no energy losses, such as the combustion of fuel in air in an isolated vessel, yet the process is highly irreversible and therefore non-ideal [46]. The low efficient heating system leads to enormous energy loss and causes a serious problem of environmental pollution [47]. Building sector account for the most energy loss waste on earth, owing to the low thermal insulation level of the envelopes, high thermal dispersions and minimum exploitation of the climatic resources. The primary

Table 8
World transportation sector delivered energy consumption by region, 2010–2040 (quadrillion Btu).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD	**57.9**	**56.0**	**55.9**	**54.8**	**54.5**	**54.8**	**55.5**	**−0.1**
Americas	32.7	32.5	32.5	32.0	31.7	32.0	32.9	0.0
Europe	18.0	16.3	16.2	15.8	15.7	15.8	15.7	−0.5
Asia	7.1	7.1	7.1	7.0	7.0	7.0	7.0	−0.1
Non-OECD	**43.1**	**50.3**	**56.4**	**62.3**	**68.3**	**75.6**	**83.9**	**2.2**
Europe and Eurasia	6.7	8.0	8.5	8.9	9.5	10.1	10.6	1.5
Asia	19.9	23.5	28.0	32.5	37.0	42.6	49.2	3.1
Middle East	6.0	7.4	8.1	8.3	8.6	9.0	9.5	1.5
Africa	3.8	4.0	4.1	4.4	4.5	4.6	4.8	0.8
Central and South America	6.6	7.3	7.7	8.1	8.8	9.3	9.8	1.3
World	**101.0**	**106.2**	**112.2**	**117.0**	**122.8**	**130.4**	**139.5**	**1.1**

Table 9
OECD and non-OECD net electricity generation by energy source, 2010–2040 (trillion kilowatthours).
Source: Ref. [19].

Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010–2040
OECD								
Liquids	0.3	0.3	0.2	0.2	0.2	0.2	0.2	−1.1
Natural gas	2.4	2.7	2.9	3.1	3.5	3.9	4.3	2.0
Coal	3.5	3.3	3.3	3.3	3.3	3.3	3.3	-0.2
Nuclear	2.2	2.1	2.4	2.6	2.7	2.7	2.7	0.7
Renewables	1.9	2.4	2.8	3.0	3.2	3.4	3.7	2.2
Total OECD	**10.3**	**10.8**	**11.5**	**12.2**	**12.9**	**13.5**	**14.2**	**1.1**
Non-OECD								
Liquids	0.6	0.6	0.6	0.6	0.5	0.5	0.5	−0.9
Natural gas	2.1	2.3	2.6	3.1	3.7	4.4	5.0	3.0
Coal	4.6	5.9	6.9	8.0	9.0	9.9	10.6	2.9
Nuclear	0.4	0.8	1.3	1.7	2.1	2.5	2.8	6.3
Renewables	2.2	2.9	3.7	4.2	4.7	5.3	5.9	3.3
Total non-OECD	**9.9**	**12.5**	**15.1**	**17.6**	**20.1**	**22.6**	**24.8**	**3.1**
World								
Liquids	0.9	0.9	0.8	0.8	0.7	0.7	0.7	−1.0
Natural gas	4.5	5.0	5.5	6.2	7.2	8.3	9.4	2.5
Coal	8.1	9.2	10.1	11.3	12.3	13.2	13.9	1.8
Nuclear	2.6	2.9	3.6	4.3	4.8	5.1	5.5	2.5
Renewables	4.2	5.3	6.5	7.2	7.9	8.8	9.6	2.8
Total World	**20.2**	**23.3**	**26.6**	**29.8**	**33.0**	**36.2**	**39.0**	**2.2**

energy use for average European electricity is nearly three times higher than European electricity end use energy because the energy losses in the electricity production processes and in the distribution [48].

The residential sector consumes secondary energy. Secondary energy is that received in suitable form for use by the consuming systems to support the living standards of occupants. In space heating (SH) and space cooling (SC) which is one of the major end-use groups of secondary energy, energy required to support thermal losses incurred across the building envelope due to conduction and radiation, as well as air infiltration/ventilation in an effort to maintain the living space at a comfortable temperature and air quality [49].

In industry, large plants with high energy consumption tackled the problem by retrofitting process plants and facilities. Other industrial sectors resorted to investments with the shortest possible payback such as heat recovery and reduction of losses [50]. Energy losses in a large number of industries exist, and there is potential for energy efficiency improvements. Energy research organizations and government are actively engaged in developing methods of assessing energy efficiency. One of the ways to attain a more efficient use of final energy in an industry is to determine the amount of energy used and energy losses. Large- and medium-sized plants should have their own energy conservation department, which may be responsible for managing energy losses and hence reducing specific energy uses [51].

Leaks represent a significant source of wasted energy in the industrial compressed-air systems. Air leaks are the single greatest source of energy loss in manufacturing facilities with compressed air systems. Leaks can waste 20–50% of a compressor's output. Stopping leaks can be as simple as tightening a connection or as complex as replacing faulty equipment such as couplings, fittings, pipe sections, hoses, joints, drains, and traps [50].

The benefit coming from the rail is the result of the combination of two important factors: the transport capacity and the use of electric energy thanks to the efficiency of the electric drive system. The comparison is based on a well-to-wheel approach and hence includes the energy losses corresponding to electricity production and transport. Diesel–electric motorization, when used for urban buses, offers a very good flexibility for the drive system mainly in starting and acceleration conditions. But the multiplication of the efficiency of the different components of the drive train leads to a supplementary energy consumption of 10–20% compared to an equivalent thermal vehicle. This loss of energy is in this case very difficult to compensate even with good drive train integration [52].

An emerging consensus suggests that bioenergy should initially be used for heat generation, and/or co-generation, rather than in the transportation sector. The main reason for this is the larger energy losses that are involved when converting biomass into liquid or gaseous forms. This means that you get more CO_2 reductions when using 1 GJ of biomas s for heating than if converted into, say methanol, and used in the transportation sector [53].

To supply biomass from production areas to energy importing regions, long-distance international transport is necessary, implying additional logistics, costs, energy consumption and material losses compared to local utilization. International bioenergy trade is possible against low costs and modest energy loss. Some regions have a much larger bioenergy production potential than others, due to a combination of large land areas with good crop production potential, low population density and extensive agricultural practices. Consequently, some countries may become net suppliers of renewable bioenergy to other countries that are net importers. This could require transport over long distances, and hence additional logistics, costs, energy use and material losses. A few earlier studies have given indications that intercontinental trade of biofuels or bulk wood could be economically feasible and does certainly not lead to dramatic energy losses [54].

The electric power sector also consumes energy. The electricity it produces is consumed by the end-use sectors. There are also losses in electricity generation, transmission, and distribution. The electricity consumed by the four major energy end-use sectors and electricity losses can be apportioned to these respective end-use sectors to calculate their total energy use. Losses are the difference between the amount of energy used to generate electricity and the energy content of the electricity consumed at the point of end use. Table 10 gives world energy consumption by end-use sector (quadrillion Btu) and shares of total energy use in 2011 (includes losses in electricity generation, transmission, and distribution). Energy end-use includes end-use of electricity but excludes losses, electricity losses includes lossess in generation, transmission, and distribution and total energy use includes electricity losses in Table 10 [19].

The bulk of electricity consumption in the industrial sector is by electric motors. Activities and processes in the industry depend

Table 10
World energy consumption by end-use sector (quadrillion Btu) and shares of total energy use, 2011.
Source: Ref. [19].

End-use sectors	Energy end use	Electricity losses	Total energy use	Share of total ?energy ?use (%)
Commercial	29	34	62	12
Industrial	200	66	266	51
Residential	52	40	92	18
Transportation	101	2	103	20
Total end-use sectors	382		524	
Electric power sector	204			39
Total electricity losses	142			

heavily on electric motors include compacting, cutting, grinding, mixing, fans, pumps, materials conveying, air compressors and refrigeration. There are four basic types of losses in a squirrel-cage induction motor: Stator and Rotor losses, Core (Magnetic) losses, Friction and windage and Stray losses [50].

3. Environmental impact of global energy consumption

This topic is not new. Wood burning has contributed to the deforestation of many areas. Wood and coal burning in building and power plants have some air polluting problems [55].

Environmental impacts can come in a wide variety of forms, thus the need to characterize them, at least in general terms. There are three general classifications of the impacts of energy use: (1) classification by source; (2) classification by pollutant; and (3) classification by scale [25].

How do we compare the widely disparate environmental impacts of different energy systems? First, we must be able to understand the range of impacts of complete energy systems. There are resource impacts. Every energy source has some impacts associated with various stages of the production, conversion, and end-use of the energy. In reality, the environmental impact needs to include the impacts of the additional (coal or nuclear) power plants and their fuel use. Depletion of fossil fuels is a resource impact, but not truly an environmental one. Whereas the depletion of forests from firewood demand or clearing land for agriculture is a major environmental impact, some land use incurs less environmental cost than others. If the land can have multiple uses, the impact is lower. Land and water use are related impacts. These are both systems that play essential roles in the well-being of the environment. Rational evaluations of energy use in societal structures make it obvious that humanity has benefitted greatly from the use of fossil and nuclear fuels as primary energy sources. However, it is equally obvious that the scales with which we use them have resulted in a number of negative impacts on Earth's atmosphere, waterways, and ecosystems. These impacts can often be quantified in terms of change to existing natural systems, as well as in the monetary costs associated with impact on society, including those related to health [25].

Public policies encouraging the insertion of large industrial and commercial developments near highways, associated to exclusionary housing policies, have shaped over the past decades a new urbanization phenomenon; the sprawl. This is largely characterized by discontinuous and fragmented occupation, with random population densities. This phenomenon brings environmental and social impacts to the urban and rural population, in addition to a great burden for the Government. The large concentration of cars, buildings and people in denser areas, such as central regions, represents smaller green areas like parks and squares, while more isolated gated communities stand for the image of environmental satisfaction and quality of life [56].

Urban sprawl has important implications for climate change and the world economy. Urban sprawl aids in the consumption of industrial output because it increase demand for automobiles. Urban sprawl is a key factor behind the massive amounts of carbon dioxide emitted by the world economy. Urban sprawl necessitates the usage of relatively large amounts of energy. This energy is needed for the long commuting distances via automobiles required in the context of difuse urban development. As shown Table 11, in 1990 there were 604, 491, 524, 392, 123 and 102 automobiles per one thousand people [57].

New technological advances will make up for the dramatic increases in vehicle miles driven. The increase in auto and truck travel is the key force behind the energy consumption, air quality impact, and climate changes. We are starting to give back air quality gains because sprawling development patterns demand more driving. Table 12 compares the land and air impacts of development at densities [58].

Table 11
Comparative urban automobile use.
Source: Ref. [57].

Region	Automobile ownership (per 1000 people)	Average automobile use (km)	US automobile use /other areas automobile use
US cities	604	11155	–
Australian cities	491	6571	1.70
Canadian cities	524	6551	1.70
European cities	392	4519	2.47
Wealthy Asian cities	123	1487	7.50
Developing Asian cities	102	1848	6.04

With the explosive growth in energy consumption, there has necessarily been correspondingly rapid growth in the release of combustion products [9]. Combustion products (especially CO_2) are accumulating in the atmosphere. In addition carbon, oxides of sulfur and nitrogen are also converted to acids [10]. If consumption is assumed to be the key economic driving force steering the environmental transformation, the assessment of the environmental performance of the national economy requires us to distinguish between environmental impacts created by a nation's residents and the emissions generated within national boundaries [59]. Nitrogen oxides (NO_x) and sulfur oxides (SO_x) are major combustion-generated pollutants from coal-fired power plants [60–66].

Climate change and growing Greenhouse Gas emissions are widely discussed issues nowadays [67]. The climate has been rapidly changing because of the rise in the concentration of CO_2 and other Green House Gases (GHG) in the atmosphere. Global warming on the Earth is the result of emissions of CO_2 and other climate changing gases [22]. Climate change and energy security represent two of the most pressing problems for current and future generations [6]. As climate change is becoming a key political issue, and oil prices rise, society has become acutely aware of this issue. Also, as a limited resource, energy can become a major source of conflict, which is another direct threat to sustainability [3].

Global climate change issues are high on the agenda for both the scientific community and policy makers [68]. Global warming is considered an average increase in the Earth's temperature due to greenhouse effect as a result of both natural and human activities [69].

The impacts of GHG emissions and the resulting climate change have a serious impact on the global economy, so the need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country [70,71]. Half of our greenhouse gas emissions (GHGs) are created in cities. Mayors can often influence the running of their city and they can address the challenges we face in a coherent way, be it in the field of development of alternative energy or pollution control, energy management or a change of behavior by public authorities and citizens. Cities are the privileged places where it is possible to find multicultural, cross-sectoral solutions and where the necessary balance between private and public interests may be found [72].

Efficient consumption of energy is widely viewed as a rather inexpensive way to cut total energy consumption and thus greenhouse gas emissions. Many agencies at national and international levels recommend energy efficiency measures. These measures in fact act as a way to reduce significant amounts of green house gas

Table 12
Projected environmental impact of 400 000 new housing units.
Source: Ref. [58].

Density (acres per unit)	Land used (thousands of acres)	Vehicle miles traveled per year (thousands)	Fuel used (thousands of gallons per year)	Emissions (in thousands of pounds per year)					
				CO	NO_x	CO_2	VOCs	Impact on land consumption (%)	Impact on air qality (%)
5	2000	12000 000	413793	422068	29379	6620 689	56275	100.0	100.0
1	400	11000 000	379310	386896	26931	6068 965	51586	20.0	92.0
0.125	50	6000 000	206896	211034	14 689	3310 344	28137	2.5	50.0
0.02	8	3200 000	110344	112551	7834	1765 517	15006	0.4	27.0

emissions without incurring real cost and promise potential net benefits. The continued growth of global emissions and their possible adverse effects on global warming have shifted focus to relative contribution in total emissions and size of relative efforts undertaken by countries to mitigate these emissions [73].

The further increase of CO_2 will lead to disastrous effects on the Environment. The emission of SO_x and NO_x and suspended particulate matters will substantially contribute to exasperate the effect on the environment [74].

3.1. CO_2 emissions

CO_2 is the most important Green House Gas that originates from the burning of hydrocarbons, decomposition of biomass, e.g., from plants as well as from the respiration processes of humans and animals [22].

The industrial revolution in the eighteenth and nineteenth century has had a profound impact on every aspect of human activity. A by-product of this revolution has been the massive generation of greenhouse gases, most importantly, CO_2. There has been a consistent increase of anthropogenic CO_2 emissions since the beginning of the industrial revolution. Over the period of 2000–2008, there has been an acceleration of CO_2 emissions associated with strong economic growth in China and other Asian countries yielding increased demand for coal-based electricity and petroleum based cars and trucks. In 2008, humanity emitted almost 30 billion tons of CO_2. Emissions of such a magnitude are unsustainable, and if not dramatically reduced, can yield potentially catastrophic climate change [75].

Climate change is becoming more evident to everybody and there is an urgent need for action. The need for a worldwide reduction of CO_2 emissions is only sporadically doubted. The required extent of this reduction is also largely clear. However, there is continuing argument over how much contribution to this should be made by the individual countries and regions of the world. Measurable indicators based on the two main aspects, namely energy efficiency and CO_2 intensity, should enable the efforts to be judged equitably [76].

The researchers explore two major environmental concerns that arise from fuel use: the globe will become warmer as a result of emissions of carbon dioxide, and the effect upon health of the fine particles emitted as combustion products. There was lack of data direct enough to enable us to predict an entirely satisfactory result, and that makes policy options particularly difficult. In the second half of the 20th century, there were major increases in anthropogenic CO_2 emissions, and it is generally agreed that these were responsible for an increase in CO_2 concentrations [77].

The role of forest sector in sequestering atmospheric carbon dioxide have long been recognized by scientists and policy makers, and interest in using forests in climate change mitigation efforts has been growing. Examples of how the forest sector can be used to mitigate greenhouse gas accumulation include avoiding deforestation or protecting existing forests, planting new forest area, decreasing harvest intensity, increasing forest growth, increasing carbon storage in harvested wood products (HWP), using wood biomass for energy to replace fossil fuels, and substituting wood for fossil-fuel intensive products [78].

Table 13
OECD and non-OECD energy-related carbon dioxide emissions by fuel type, 1990–2040 (billion metric tons).
Source: Ref. [19].

Region/ country	1990	2010	2020	2030	2040	Average annual percent change, 2010–2040
OECD	**11.6**	**13.1**	**13.0**	**13.4**	**13.9**	**0.2**
Liquid fuels	5.5	5.8	5.7	5.6	5.7	−0.1
Natural gas	2.0	3.0	3.4	3.7	4.1	1.1
Coal	4.1	4.2	4.0	4.0	4.0	−0.2
Non-OECD	**9.8**	**18.1**	**23.4**	**28.1**	**31.6**	**1.9**
Liquid fuels	3.6	5.4	6.6	7.7	9.0	1.7
Natural gas	2.0	3.2	3.8	4.9	6.0	2.2
Coal	4.2	9.6	13.0	15.5	16.6	1.8
World total	**21.5**	**31.2**	**36.4**	**41.5**	**45.5**	**1.3**

Energy consumption is an important component of the global climate change debate because much of the world's anthropogenic greenhouse gas emissions relate carbon dioxide emissions. World energy-related carbon dioxide emissions increase from 31.2 billion metric tons in 2010 to 36.4 billion metric tons in 2020 and 45.5 billion metric tons in 2040 (Table 13) [19]. In 2003 China emitted an estimated 3.5 Gt of CO_2, compared with 5.8 Gt by the United States, but by 2010 China had increased its emissions to 8.95 Gt whereas those of the United States had decreased to 5.25 Gt, though China's per capita emissions are still 2.5 times less than those of the USA (see Table 14) [79].

3.2. SO_x emissions

SO_x are the oxides of sulfur. Coal and petroleum often contain sulfur. Therefore, combustion of coal and petroleum generates SO_x. These SO_x are harmful to the environment, as their further oxidation produces H_2SO_4, leading to acid rain. The utilization of SO_x has increased in recent decades due to its specific utility as a preservative, reducing agent, refrigerant, reagent, solvent in laboratories, etc. This has brought an unpleasant change in the environment shaken the experts. Its contribution to global warming is huge. The oxides of sulfur are considered to be one of the major GHGs that contribute to global warming [80].

Table 14
Carbon dioxide emissions in 2010 (Mton CO_2) and per capita emissions 1990–2010 (ton CO_2 per person) (includes cement production, −8% of global total).
Source: Ref. [79].

	CO_2 emissions 2010 (Mt)	Per capita CO_2 emissions (t per person)			Change since 1990 (%)	
		1990	2000	2010	CO_2	Population
United States	5250	19.7	20.8	16.9	5	23
EU-27	4050	9.2	8.5	8.1	−7	6
Russian Federation	1750	16.5	11.3	12.2	−28	−4
Japan	1160	9.5	10.1	9.2	0	4
Australia	400	16.0	18.6	18.0	46	30
Canada	540	16.2	17.9	15.8	20	23
China	8950	2.2	2.9	6.8	257	17
India	1840	0.8	1.0	1.5	180	40
South Korea	590	5.9	9.7	12.3	134	12
Indonesia	470	0.9	1.4	1.9	194	30
Brazil	430	1.5	2.0	2.2	96	30
Mexico	430	3.7	3.8	3.8	39	35
Saudi Arabia	430	10.2	12.9	15.6	159	70

Sulfur dioxide, SO_2 molecules are dangerous to human health and form acid rain. In addition, SO_2 is an important aerosol creator and lowers the temperature of the atmosphere through dispersion of sunlight. The climate role of SO_2 is not yet completely clear [22].

Using fuel prices coupled with environmental concerns to arrest SO_x emissions is forcing organizations all over the world to adapt new protocols and fuel standards with the aim to lower the sulfur contents in the fuel to keep SO_x emissions in check and in tandem equally optimize the capital spending on fuel [81].

3.3. NO_x emissions

Nitrogen oxides (NO_x) play a vital role in tropospheric chemistry. Production of ozone in the troposphere is controlled by the abundance of NO_x. NO_x also contributes to the formation of secondary inorganic aerosols, resulting in adverse impacts on human health. In addition, NO_x may lead to climate forcing effects via ozone formation or via secondary aerosols. Therefore, NO_x is a key pollutant for the overall improvement of ambient air quality under multi-objective environmental management policies [82].

For higher ozone non-attainment rating the NO_x emission limits are also more stringent. The most stringent NO_x emission standards can only offset the increases in emissions as long as population growth and mobile source emission continue to increase [83].

NO_x comprises the various oxides of nitrogen such as nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), dinitrogen trioxide (N_2O_3), dinitrogen tetroxide (N_2O_4) and dinitrogen pentoxide (N_2O_5). N_2O accounts for about 7.9% of total GHG emissions (IPCC, 2007), which highlights the significance of the contribution of NO_x to global warming. In addition, it damages our lung tissues and causes emphysema, bronchitis, etc. In actual flue gas, the total NO_x emission level varies from several hundreds to thousands ppm with more than 90–95% NO and 5–10% NO_2 [84].

Natural sources of nitrogen oxides, such as NO, NO_2 and other nitrogenous substances, are caused by lightning and microbes in the ground. However, improvement in fuel efficiency have been achieved through the development of modern internal combustion and jet engies, which operate at higher temperatures and higher pressures than in the past. Unfortunately, these improvements also increase the formation of nitrogen oxides, which can be reduced through further changes in the combustion chamber or in an appropriate exhaust gas after treatment system [22].

4. Conclusions

A impression of future energy consumption is an important input to many analyses of economic, energy, and environmental policies. This paper focuses on energy consumption and it will provide an overview of the literature on personal consumer decisions about sustainable energy consumption.

The increase in energy prices has caused to focus on energy consumption. We must to detect abnormal and unusual increases or decreases in consumption, to identify and evaluate conservation options and should take into account environmental impact of energy consumption. This paper draws conclusions on the determinants of global energy consumption at macro level in order to analysis the effects of energy users. This study at macro level is useful because of the large number of variables that influence energy consumption. This paper aims to assess and explain the factors causing the growth of energy consumption. The current generation of energy technologies are not capable of achieving the level of mitigation required. Next generations of renewable, low carbon generation and end use technologies will be needed.

The future of energy consunption is fundamental to global economic growth and sustainability. Climate change, growing energy demand and limited resources will urge people to adjust their energy landscapes and address future energy needs. Renewables must dominate the global energy consumption and substitute the more polluting traditional energy sources because traditional sources such as coal, crude oil and natural gas are not only harmful to the environment but also are finite in the long term.

More innovative solutions are needed for energy consumption. Additional technological developments will be crucial to make renewable energy a success story in energy consumption. Extra ordinary increase in consumption will require a global effort. One of solutions is to use energy efficiently. Industries will provide the next generation of energy efficient products for consumers in the future.

The most of the data given in this study have been taken from the IEO2013 Reference case because the energy balances published by the International Energy Agency (IEA) are one of the most valuable sources of energy statistics covering world energy supply and demand. I hope this paper will prove useful to all those interested in the connections between energy production, energy use, energy security, and the role of energy policies. I hope this paper provides a unique source of potential solutions for reduction and environmental impact of global energy consumption.

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