RENEWABLE ENERGY FOR SUSTAINABLE DEVELOPMENT AND THE IMPACT ON THE GLOBAL ECONOMIC SYSTEM

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ABSTRACT

Purpose: Energy has been always the main driver of human civilisation. This paper highlights the impact of switching from fossil fuel to renewable energy on the global economic system.

Methodology: In this paper, we discuss the unavoidable future reliance on renewable energy sources. This is achieved by investigating the global energy needs map and the future market shaped by the new technological development, and its impact on the global economic system.

Findings: This work investigates the influence of oil companies worldwide on the global economic system, and their struggle for survival when faced with ever rising and developing renewable energy systems. However, even for the foreseeable future, oil companies will not completely vanish; this is because certain oil products are used in applications and uses beyond the reach of renewable energies. In this work we also highlight the efforts deployed to produce environmentally friendly nuclear energy.

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Value: Energy is a key factor in shaping the development of nations. There is a global consensus on the negative impact of fossil fuel on the environment, and on the importance of developing alternative clean energies.

Keywords: Renewable energy; Sustainable development; Global economic system; Solar energy; Nuclear energy

INTRODUCTION

Since antiquity, energy has always been the source of advancement of civilisations. It is the driver of humankind to excel in various disciplines related to their daily life. In the first part of this paper we discuss the problem of harnessing energy as a measure for classifying the degree of advancement of cosmic civilisations, and the position of the Planet Earth in this classification.

Wood and coal were the main sources of energy for millennia. However, certain historians claim that the earliest oil wells were drilled in China in 347AD or earlier (Dalvi, 2015). The oil was burned to evaporate brine and produce salt. Ancient records of China and Japan referred to the allusions of using natural gas for lighting and heating. Petroleum was known as *burning water* in Japan in the 7th century (Chisholm, 1911). Fossil fuel today constitutes the main source of energy. Oil, gas, and coal are among the main drivers of the economic system worldwide, and they are also the main threat to the environment. In the second part of this paper we highlight the available gas and oil reserves in various countries, and emphasise their potential impact on the environment and on the stability of the world's economic system. Nuclear ores, such as uranium and thorium, have been attractive to many advanced countries as a source of energy. The impact of using nuclear fission or thorium to produce energy is highlighted and discussed.

In the third part of this paper, we introduce solar energy as a clean everlasting source of energy. The solar energy distribution around the globe and its consequences are discussed.

In the last part of this paper, we discuss how the global oil and gas companies impact the world economy.

ENERGY: A COSMIC PERSPECTIVE

It is interesting to identify the level of Earth's future energy needs. Harnessing available energy resources while safeguarding the environment will be one of the major challenges that humanity needs to seek for survival. Energy consumption is regarded by scientists as a viable element for measuring the degree of advancement of a cosmic civilisation. Recent astronomical observations using different methods to discover extra solar planets reveal the existence of billions of planets in our galaxy alone. Statistically, using the Drake equation (Burchell, 2006), an important number of advanced cosmic civilisations exist that are capable of establishing radio or other means of intergalactic communication and beyond. The Kardashev scale is designed to measure the level of technological advancement of a civilisation based on the amount of energy used for communication. The scale identifies three categories of civilisation (Kardashev, 1964):

- **Type I civilisation**, also called a planetary civilisation, can harness all of the energy received from the parent star. In the case of the Sun, this energy amounts to 7×10^{17} watts; this is five orders of magnitude higher than the amount presently attained on Earth (4 × 1012 watts) (Kardashev, 1964);
- **Type II civilisation**, also called a stellar civilisation, can harness all the energy produced by its parent star. In the case of the Sun, the energy utilisation would then be comparable to its luminosity, or 4×10^{26} watts (Lemarchand, 1994);
- **Type III civilisation**, also called a galactic civilisation, can harness energy on the scale of its entire host galaxy. For our galaxy, the energy utilisation would then be comparable to the luminosity of the entire Milky Way, or about 4×10^{37} watts (Lemarchand, 1994).

Michio Kaku suggested that humans may attain Type I status in 100–200 years, Type II status in a few thousand years, and Type III status in 100,000 to a million years (Kaku, 2010).

The above energy consumption of the planet Earth traces a viable energy road map for future generations. There are many implications resulting from human civilisation undergoing large-scale transitions. As an example, the transition between Kardashev scale levels could potentially lead to a dramatic period of social upheaval, because it may entail surpassing the ultimate limits of the resources available in a civilisation's existing territory. Scientists speculate that the transition from a Type 0 to a Type I civilisation might carry a strong risk of self-destruction, since, in some scenarios, the room for further expansion on the civilisation's home planet becomes highly restricted (Dyson, 1960).

Figure 1 shows the total world annual primary energy consumption. It increases almost linearly at an annual rate of 133 million tonnes equivalent. The total consumption in 2008 amounted to 11,000 billion barrel equivalent. Extrapolating the data, we obtain a total energy consumption of 12,200 billion barrels for the year 2017.

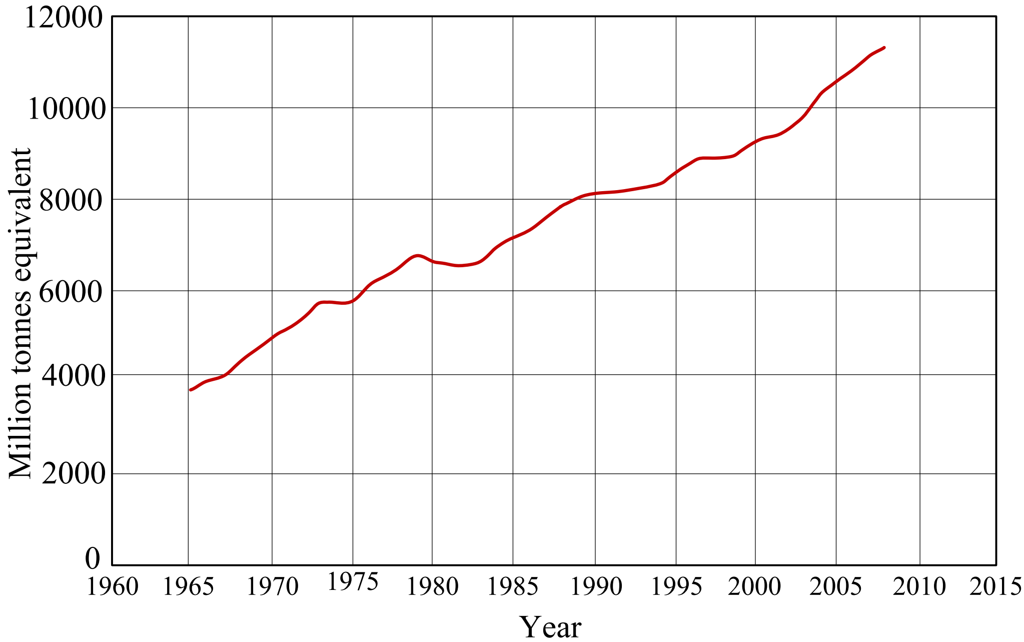

Figure 1 Total World Annual Primary Energy Consumption
Source: http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports

The excessive consumption of energy without adequate disposal of heat, for example, could affect the planet Earth when approaching a Type I civilisation, in a way that is unsuitable to the biology of the dominant life-forms and food chains. The rise of sea temperature to 35ºC on planet Earth, for example, would jeopardise marine life. As a conclusion, the Kardashev scale is a viable tool for measuring the degree of advancement of a civilisation.

FOSSIL SOURCES OF ENERGY

Oil, gas, coal, uranium, and other nuclear materials are the main sources of energy today. A common feature of these sources is their negative impact on the environment. However, an important number of developed countries depend heavily on fossil fuel resources, and a switch to clean energy for the foreseen future is restricted to certain sectors where a balance between economy and pressure from environmental bodies play a major part. In the following sections, we highlight the reserves and energy production from different types of fossil fuel. We shall also address the contribution and impact of each of these sources of energy.

Oil and Gas

Oil and gas today constitute the main fossil fuels used by different countries to satisfy their energy needs. The market for these energy sources shapes the world economy, and is at the origin of major conflicts after World War II. In 2016, the total world oil reserve was 1,492 billion barrels. The OPEC share amounted to 81% of the total oil world reserve. Among the most oil productive OPEC countries are Venezuela, Saudi Arabia, Iran, Iraq, Kuwait, and United Arab Emirates. Their total oil reserve was 1,073.73 billion barrels, or about 72% of the total world oil reserves. The trend in the change of oil reserves for the top five countries (1980—2013) is shown in Figure 2.

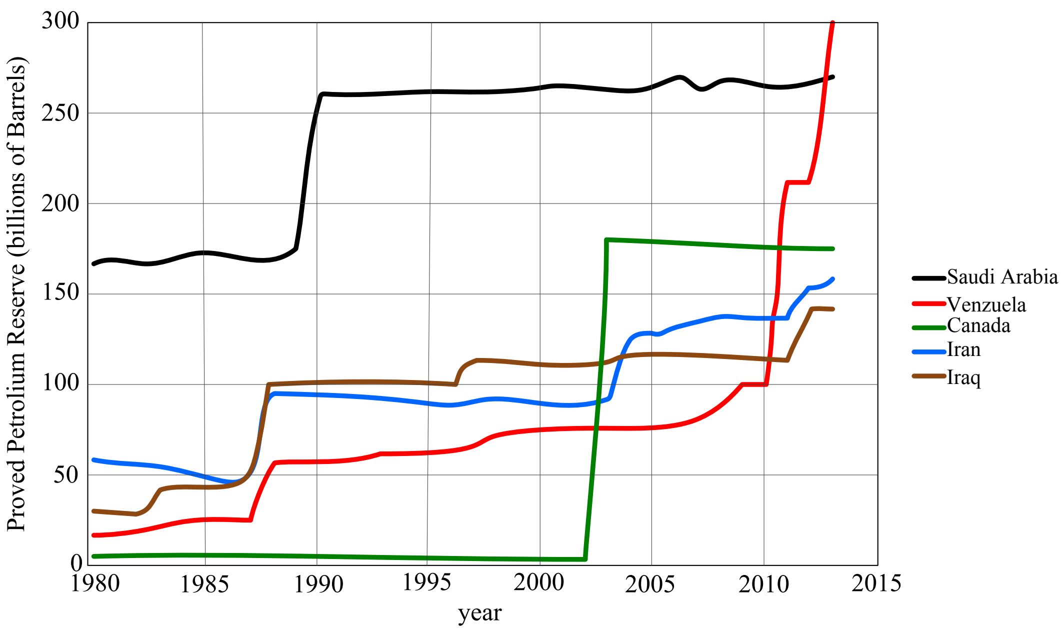

Figure 2 Trends in Proven Petroleum Reserves, Top Five Countries, 1980—2013

Source: Data from US Energy Information Administration

The world natural gas reserves amounted to 200 trillion cubic metres in 2012. They are increasing at a constant rate of about 3.4 trillion cubic meters a year, as shown in Figure 3. Russia, Iran, Qatar, USA, and Saudi Arabia are at the top of the list of natural gas reserves owners.

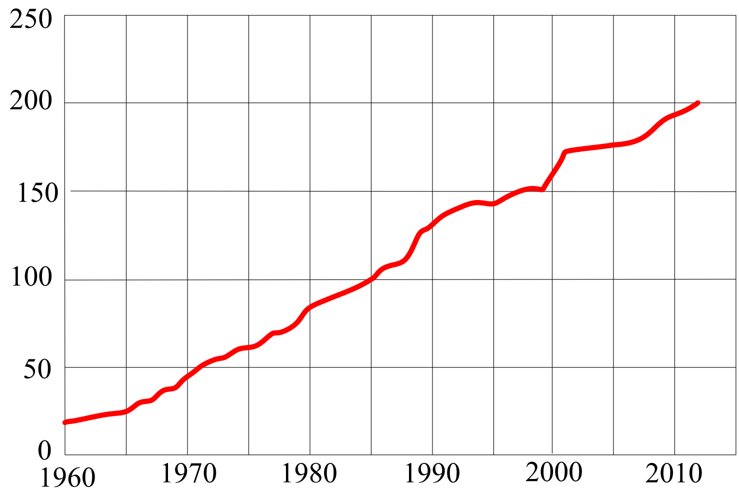

Figure 3 **World Natural Proven Gas Reserves (1960—2012)**

Source: OPEC

The proven gas reserves in the top five gas producing countries is shown in Figure 4: Russia has by far the greatest proven gas reserves.

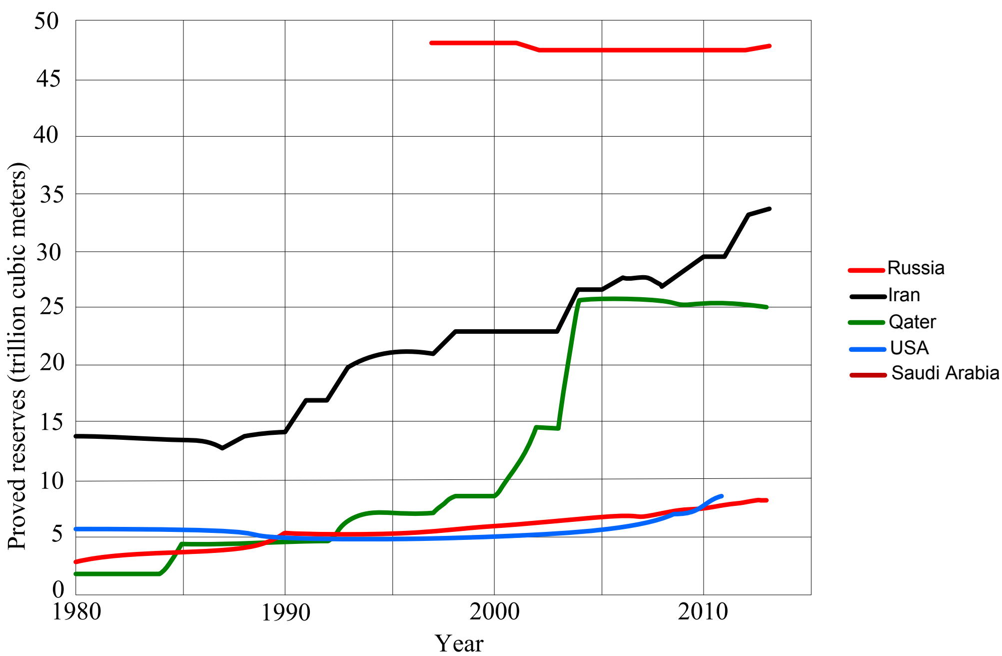

Figure 4 **Proven Gas Reserves in the Top Five Countries, 1980—2013**

Source: US AIA

Coal Reserves

Planet Earth has an appreciable amount of coal reserves: these reserves are sufficient to meet 153 years of global production. The United States alone possesses 25% of the total world coal reserves. It mined about 900 million tonnes in 2015, and most is destined for domestic electricity generation. The USA, Russia, China, India, Australia, and South Africa are among the leading countries of coal reserves (see Table 1).

Of all the fossil-fuel sources, coal is the least expensive for its energy content, and it constitutes a major factor in the cost of electricity in the United States. However, CO_2 emissions may have a drastic implication on the environment. To reduce the effect of harmful emissions, gases are allowed to pass through scrubbers or other developed technologies that remove pollutants. Even so, the smoke still contains nitrogen oxides and sulphur dioxides that cause smog and acid rain. Fortunately, advanced technologies are being developed to reduce harmful emissions. However, these new technologies are not equally developed among all countries. Pollution has no border and can contaminate the Earth's atmosphere with all known consequences. Coal makes up 42% of US electrical power generation and 65% in China (Morse, 2012).

Table 1 Coal Production in 2007

Rank	*Country*	*Production*	*Share*
	World	6395.6	100
1	China	2536.7	39.7
2	United States	1039.2	16.2
–	European Union	590.5	9.2
3	India	478.2	7.5
4	Australia	393.9	6.2
5	Russia	314.2	4.9
6	South Africa	269.4	4.2
7	Germany	201.9	3.2
8	Indonesia	174.8	2.7
9	Poland	145.8	2.3
10	Kazakhstan	94.4	1.5
11	Turkey	76.6	1.2

Source: Statistical Review of World Energy 2008

ENERGY FROM NUCLEAR FISSION

Nuclear fission was developed during the period from 1895 to 1945, with an accelerated pace during the last six of those years. Much of the efforts during the period 1939—45 were focused on the production of the atomic bomb. From 1945 research was concentrated on harnessing fission energy in a controlled fashion for naval propulsion and for generating electricity. An important number of countries have joined the nuclear fission club since 1945. Today, 16 countries depend on nuclear fission power for at least a quarter of their electricity needs. The United States alone produces 798TWh of nuclear power; France comes next with around 419TWh, representing three quarters of its power from nuclear energy. Other countries, such as the Czech Republic, Sweden, Switzerland, Belgium, Finland, Slovenia, Hungary, Ukraine, and Slovakia produce one third or more of their needs of power from nuclear fission. Figure 5 shows the nuclear generation via fission by country in 2015.

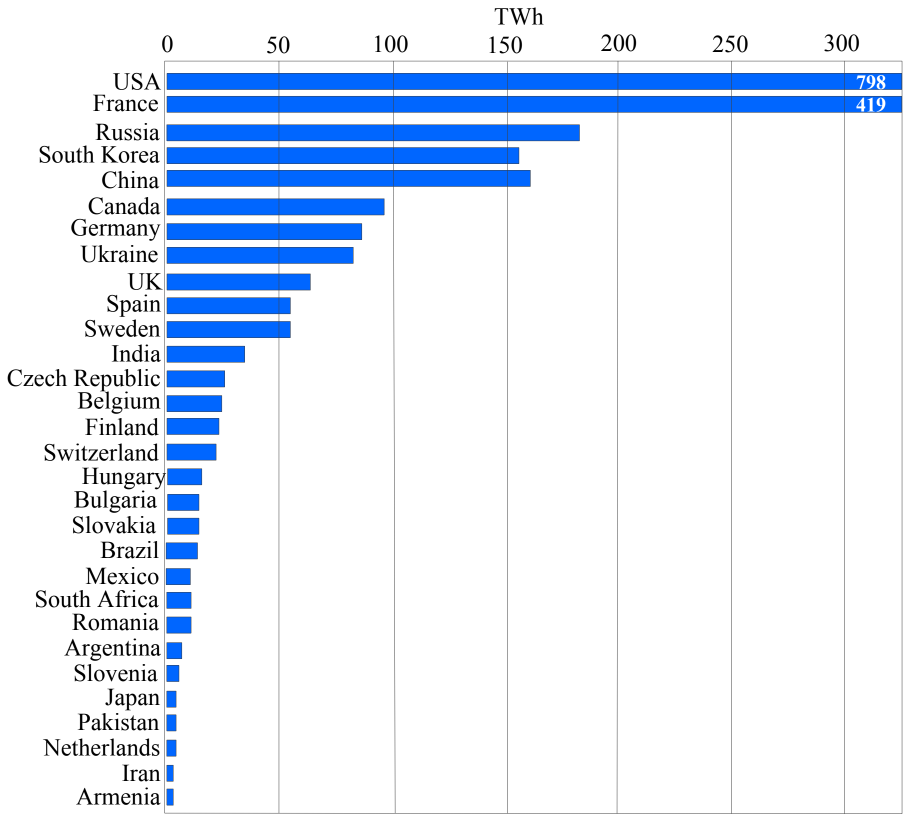

Figure 5 Nuclear Generation by Country (2015)

Source: IAEA PRIS Database

THORIUM-BASED NUCLEAR ENERGY

Thorium is a chemical element high up in the periodic table with atomic number 90. It was discovered in 1829 by Norwegian amateur mineralogist Morten Thrane Esmark, and identified by the Swedish chemist Jöns Jacob Berzelius in 1828. Thorium is slightly radioactive, and is found in small amounts in most rocks and soil. It is three times more abundant than uranium. Like uranium, it exhibits properties allowing it to be used as fuel. Thorium was formerly used as an alloying element in welding electrodes, and as a material in high-end optics and scientific instrumentation; it was also used as a light source in gas mantles. However, these uses become marginal when it was realised that thorium could replace uranium as a nuclear fuel in nuclear reactors.

The renewed interest in thorium has been highlighted in a number of scientific conferences. A nuclear reactor is fed with specific fissile isotopes to generate energy. The three most practical nuclear reactors are fuelled with uranium-235, plutonium-239, and uranium-233, transmuted from thorium-232. The latter is derived from natural mined thorium. It is believed that thorium is a key to developing a new generation of cleaner, safer nuclear power (The Energy From Thorium Foundation Thorium). The advantage of using thorium as a fuel for reactors is that it produces up to two orders of magnitude of nuclear waste)Moir and Teller, 2005(. Chinese scientists claim that hazardous waste will be a thousand times less than with uranium (Evans-Pritchard, 2010). At the same time, the radioactivity of the produced waste drops to a safe level

Table 2 World Thorium Reserves (2007)

Country	*Tonnes*	*%*
Australia	489,000	18.7%
USA	400,000	15.3%
Turkey	344,000	13.2%
India	319,000	12.2%
Brazil	302,000	11.6%
Venezuela	300,000	11.5%
Norway	132,000	5.1%
Egypt	100,000	3.8%
Russia	75,000	2.9%
Greenland (Denmark)	54,000	2.1%
Canada	44,000	1.7%
South Africa	18,000	0.7%
Other countries	33,000	1.2%
World Total	2,610,000	100.0%

Source: Data taken from Uranium 2007: Resources, Production and Demand, Nuclear Energy Agency (June 2008), NEA#6345 (ISBN 9789264047662). The 2009 figures are largely unchanged. Australian data from Thorium, in Australian Atlas of Minerals Resources, Mines & Processing Centers, Geoscience Australia after just one or few hundred years. It is estimated that one tonne of thorium can generate as much energy as 200 tonnes of uranium or 3,500,000 tonnes of coal (Evans-Pritchard, 2013). Thorium is generally more cost efficient than uranium and a less environmentally damaging fuel source. Its mining is also easier than mining uranium, and less dangerous. On the other hand, thorium reactor's by-products are not suitable for making a practical nuclear bomb, and thus do not constitute a threat of nuclear weapon proliferation or the production of radioactive pollution. Table 2 below shows the world thorium reserves in 2007.

The above figures are reserves referring to the amount of thorium inventoried so far and estimated to be extractable at current market prices. The total amount of thorium existing in the Earth's crust amounts to 3×10^{19} tonnes (Ragheb, 2011; American Geophysical Union, 2007). Mining this quantity of thorium is enough to move the planet Earth towards a Type I civilisation.

RENEWABLE ENERGIES

Renewable energy is any type of energy that is naturally replenished on a human timescale. This includes direct sunlight, wind, geothermal heat, waves, tides, and nuclear fusion. We shall discuss in this paper some of these energy sources and highlight their impact on the environment and the well-being of mankind in general.

Solar Energy

The Sun is a main sequence star that fuses hydrogen to produce radiant light and heat. Active solar energy is harnessed using a range of ever-evolving technologies, including photovoltaic systems, concentrated solar radiation, solar water heating, and many other applications. Passive solar techniques include heat insulating systems, orientation of buildings, and using materials with favourable thermal properties.

In 2011, the International Energy Agency declared that, "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly important-independent resource, enhance sustainability, reduce pollution, lower the mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared" (Solar Energy Perspectives). This statement highlights the importance of clean energy sources in establishing a secure and safe world economic system.

The planet Earth receives a huge amount of solar radiation. The energy available makes this a highly attractive source of electricity. In 2000, the United Nations Development Program found that the annual solar energy was 1575—49837 exajoules (EJ = 10^{18} joules). This exceeds world energy consumption several times over; consumption was 559.8 EJ in 2012. The upper atmosphere of Earth receives 174 petawatts (PW) of incoming solar radiation, 30% of which is reflected back to space while the rest is absorbed by the clouds, oceans and land. The solar spectrum at the Earth's surface falls mostly in visible and near infrared regions of the spectrum, with a small amount in the ultraviolet region. Most of the world's population occupies areas with insolation levels of 150—300 watts/m^2, or equivalently 3.5 to 7.0kWh/m^2 per day.

The total annual solar energy absorbed by the Earth's atmosphere, ocean and land masses amounts to approximately 3,850,000 exajoules. In 2002, this amount of energy exceeded the total energy consumed worldwide during one year in one hour. The amount of energy reaching the surface of Earth is so vast that in one year it is about twice as much as will ever be obtained from all of Earth's non-renewable resources of oil, natural gas, coal, and mined uranium combined. Table 3 below shows the annual solar energy potential by region.

Table 3 Annual Solar Energy Potential by Region (Exajoule)

Maximum	*Minimum*	*Region*
7410	181.1	North America
3385	112.6	Latin America and Caribbean
914	25.1	Western Europe
154	4.5	Central and Eastern Europe
8655	199.3	Former Soviet Union
11060	412.4	Middle East and North Africa
9528	371.9	Sub-Saharan Africa
994	41.0	Pacific Asia
1339	38.8	South Asia
4135	115.5	Centrally Planned Asia
2263	72.6	Pacific OECD

Source: United Nations Development Programme and World Energy Council, 2000

The above table reveals that the Middle East and North Africa enjoy the highest annual solar energy potential. How do these important data impact the world future economy if renewable energies emerge as the main source of energy in the future? To answer this question we have to investigate the impact of big oil and gas companies on the global economic system.

GLOBAL OIL AND GAS COMPANIES IMPACTING THE WORLD ECONOMY

Oil and gas companies began to shape the world economy soon after World War II. They become the main driver of economic systems and associated political issues. The various regional wars that the planet Earth witnessed after World War II were basically the fruit of everlasting efforts by the world's leading powers to control the sources of energy. There are 48 big gas and oil companies worldwide, with a total revenue in 2015 that amounted to US$6.130 trillion. This constitutes an important share of the world's economic system. Table 4 below shows the revenue of the top 10 oil and gas companies worldwide.

Table 4 Revenue of Oil and Gas Companies as of 2015

Company name	*Revenue 2015 (US$ billion)*
Saudi Aramco	478.00
Sinopec	454.99
China National Petrolium Corporation	428.62
PetroChina	367.982
Exxon Mobil	268.90
Royal Dutch Shell	265.00
Kuwait Petrolium Corporation	251.94
BP	222.80
Total SA	212.00

Source: Wikipedia and author's own work

Some of these companies shaped the whole economic system of the countries to which they belong. Others have a wider regional or even global influence. It is clear that a sudden switch to renewable energy would cause a collapse of the world's economic system. The transformation to a new global energy source therefore has to follow a gradual trend, whereby countries relying heavily on oil and gas as the main source of their economy can adjust themselves to the promotion of other sources of income. A smooth passage to a new world economic system requires joint global efforts to solve the problems impacting this transformation. Failure to achieve this task may result in the emergence of regional or global conflicts with unforeseen consequences.

On 1 November 2017, the IMF advised energy-rich Gulf economies to speed up their diversification away from oil. The Gulf Cooperation Council has been hit hard by the collapse in crude prices that provided a major part of their finances. Following this slump, GCC members undertook fiscal measures and reforms to cut public spending and boost non-oil revenues. This is just a glimpse of the alarming situation resulting from the collapse of oil prices. Countries around the world have to set a new strategy for their economic systems to cope with the ever growing dependence on renewable energy.

CONCLUSIONS

In this paper we highlighted the various aspects impacting the world's economic system resulting from the emergence of highly competing renewable energy sources. Renewable energies can be obtained with minimum cost from natural resources and have the potential to safeguard the environment. In the first part of this paper we discussed the advancement of the Earth's civilisation according to the Kardashev scale. It was found that the planet Earth needs 100 to 200 years to switch to a Type I cosmic civilisation; this transformation may entail the potential risk of global conflicts.

Fossil fuel is highly consumed today, resulting in an alarming increase in CO_2 gas that has a devastating effect as greenhouse gas. Energy from fission is limited by available uranium ore, and produces dangerous waste that is difficult to dispose of. On the other hand, Thorium is three times more abundant than uranium and produces much lower waste products. Fusion energy produces no nuclear waste, and can be obtained easily from hydrogen available in nature, but the technology to transfer it to a practical source of energy requires decades to come. On the other hand, solar energy and other renewable energies can be harnessed freely or with minimum cost.

The economy of many influential countries today relies on oil, gas and other fossil fuel sources. Oil and gas alone provide a revenue of about US$6 trillion, which constitutes an important portion of the global world economic system. A sudden switch to renewable energy may cause a collapse of the world's economic system with all related consequences.

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