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Rihards Novikovs

COMMERCIALIZATION AND GLOBAL INVESTMENT TRENDS OF RENEWABLE ENERGY FOR CLIMATE CHANGE MITIGATION

– Statistical analysis and forecast

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TURKU UNIVERSITY OF APPLIED SCIENCES

BACHELOR'S THESIS | ABSTRACT

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Climate financing requires serious steps in the promotion of sustainable development. In the 21st century, humanity faces severe climate changes caused by extensive greenhouse gas emissions. As a social liability, it also brings economically profitable opportunities to initiate business in the alternative power sector or allocate cash in any opening renewable projects. The global trend of investing in renewable energy is primarily associated with power policies that favor larger exploitation of renewables.

This thesis explains global trends in the renewable energy market, concentrating on investment flows over the past 12 years. The researcher aims to prove the inevitability of the extended deployment of alternative power technologies on an international level. The goal of the thesis is to measure the scale and potential of renewable energy in comparison to other forms of power, like nuclear power and the energy production from fossil fuels.

Foundation of this research is a statistical analysis based on the historical data. Direction of the investment flow and its future projections identifies the most suitable global region for the adoption of alternative power generating technologies. This study also demonstrates the causes of rising power consumption levels and its effect on climate change. The research also identifies the degree to which greenhouse gas emission can be reduced through the larger exploitation of renewable energy technologies.

In addition to presenting statistical findings, the researcher correlates his key statistical findings with present climate conditions. Increasing role of developing economies and their growing contribution in financing solar cells and wind turbines projects were presented in this work. This research on the investment behaviour benefit the interest of investors and whose, who are willing to initiate their business in renewable energy related field.

KEYWORDS:

Climate change, investment forecast, sustainable development, renewable energy, energy trends, alternative power, global warming

CONTENTS

FIGURES

EQUATIONS

TABLES

APPENDIX

LIST OF ABBREVIATIONS (OR) SYMBOLS

CAGR	Compound Annual Growth Rate
CIS	Commonwealth of Independent States
CO_2	Carbon Dioxide
COP21	21^{st} Climate Change Conference in 2015, Paris
CSP	Concentrated Solar Power
EMA	Extrapolating a Moving Average
EROEI (EROI)	Energy Returned On Energy Invested
FF	Fossil Fuels, Hydrocarbons
FIT	Feed-In Tariff
GHG	Greenhouse Gas
kW	Kilowatt (Megawatt (MW), Gigawatt (GW), Terawatt (GW))
LCOE	Levelized Cost of Electricity
LRA	Linear Regression analysis
Mtoe	Million tonnes oil equivalent
NASA	National Aeronautics and Space Administration
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaics (solar cell)
RE	Renewable Energy, Alternative Energy
RQ	Research Question
RS	Research statement
R&D	Research and Development
UNEP	United Nations Environment Programme
USD	United States Dollar

1 INTRODUCTION

1.1 Background

The 21st century is facing some of the greatest environmental changes. Global warming, deglaciation, drought of rivers, stress of fresh water availability, the increased number of national calamities, erosion, the extinction of biological species, food deterioration are the major calamities fastened by recent climatic changes. To understand the primary causes for the aforementioned consequences, humanity looked deeper into past historical events - the massive increase for power consumption started from First Industrial Revolution period in 1830’s and the later intense growth of global economy and global population (Ryden, 2010).

Renewable energy sources, also called alternative energy, are natural non-depletable sources that tend to have low levels of risk and environmental impact in comparison with other energy sources (Goudie & Cuff, 2002). There are several main renewable energy (RE) sources: biomass, geothermal energy, hydropower, solar and wind power.

However, several studies suggest that the ecological impact of renewable energy may be underestimated, as it is contradictorily to measure full effects on the environment from the large-scale usage of RE technologies. As an example of one of these studies – Photovoltaics solar cells (PV) and Concentrated solar power (CSP) panels are made of silicon, the production of which is a very polluting process, as is decommission of panels (Arutynov, 2016). According to TechInsider, to rely only on solar energy, humanity needs to use panels covering an area approximately the size of Spain (Harrington, 2015). However, Arutynov believes that present-day world economy does not possess sufficient production capacities and raw materials for manufacturing the required construction materials (Arutynov, 2016, pp. 42-48). Other existent alternative energy technologies also contain considerable drawbacks.

What matters is diversification and restructuring of the modern power supply system. According to statistical review (British Petroleum, 2016), current reserves of crude oil with the prevailing consumption level will exhaust in 2067, gas – in 2069, coal - in 2129. The problem is widely acknowledged not only by society, but also by the world leaders. The Kyoto Protocol, signed by over 190 countries in 1992, is not the solution to occurring catastrophic climate changes. On the other hand, the last Paris Climate Conference may be a breakthrough in restructuring the present energy supply conditions. Signed by 195 countries, the Paris Agreement is designed to keep global warming below 2 °C and push participants progressively towards larger exploitation of alternative energy technologies (COP21, CMP11, 2015). In 2015, regulatory policies favouring RE initiatives in the power sector already existed in most developed and emerging economies covering over 87% of world population (REN21, 2016, p. 112). These business-friendly policies are not overlooked by different groups of investors.

The year of 2015 reported a new record volume of global investment flow in the renewable energy market – 286 billion USD, exceeding the previous record in 2011 by 13 billion USD (FS-UNEP, 2016, p. 12). This also reflects the 4.76% growth from the previous year. The popularity of investing in renewables is rising; therefore it is important to understand the recent trends dictating RE market rules. Recent investments by China, as well as the leading role of developing economies in renewable investment projects, significantly alter the pattern of asset allocation.

The emphasis of this research will be directed towards deeper understanding of the main RE investment trends of the 21^{st} century. In addition, current work explains different approaches used to forecast the future investment volume, based on historical data. For a wider picture, emphasis of this work is also dedicated towards climate change causes and the need for sustainable development to mitigate global warming.

1.2 Personal Motivation

The author's interest in renewables continues since his high school, during which he had conducted research on the development of renewable power sources. His second year of study in Turku University of Applied Sciences was concentrated on Masar project, started in 2014 by a group of students and the author himself. The success of Masar was recognized in a nomination among Top-10 Energy Start-Ups of 2015 awarded by a Dutch start-up accelerator - Rockstart. Rockstart offered to shift the company's office to Amsterdam, and expanded the researcher's competence through his involvement with Masar until June 2015 (Rockstart, 2015). Subsequently, the author applied for exchange studies in Russia, where a university study program allowed pursuing his topics of interest and writing several course-works on renewables. For two years, the author has professionally worked with RE, both practically and theoretically. At Masar, the author practically exercised business concepts of renewable start-ups, their challenges and opportunities, as well as meeting different respectable investors and mentors. These experiences were supported by theoretical study and related efforts at the realm of academia.

Renewable energy, without doubt, is a key future power source. Today humanity lives in a transforming era, as the share of global power generation from renewables continuously grows. Renewable power is not a panacea, the way author thought at the age of sixteen, when he was first introduced to alternative types of power generation. Nonetheless, this trend will inevitably move mankind to a new world, powered by illimitable sources.

After 2 years of working with RE, the author believes that it is the right time to push forward. Present market conditions demand specialists in the RE sector, especially considering worldwide employment in the renewable energy sector in 2015 – 8.1 million jobs (IRENA Jobs, 2016). This research is intended to contribute to a development favouring the interests of many groups, as described in Section 1.4.

1.3 Research questions and objective

The general **thesis objective** is to measure an overall effect of rising RE investment trends on climate change mitigation. This objective is approached through the following **research statements (RSs)**:

a. Identification of the global regions and the industries (among solar power, wind power, geothermal energy, hydropower and bio renewable projects) which are likely to dominate RE asset allocation in the next five years.
b. Measuring an overall effect of money allocated in the renewable market and forecasting its future investment flow.
c. Finding a link between world energy consumption and causes of the global warming.

Thesis objective is reached by setting the following **research questions (RQs)**:

1. What are the investment trends of the 21st century in RE?
2. What global regions played leading roles in global climate financing in the past dozen years?
3. What is the scale of RE compared to other power sources and what forms of renewables are likely to increase their significance in the world power market?
4. What is the impact of rising power consumption levels on the climate change?

1.4 Values and limitations of the research

Barring a significant technological breakthrough in modern energy generation technologies, this study provides guidance to social clusters and enterprises. The value of this study can be divided under several groups of interest:

- *Investors*: The study provides the guidance of changing patterns in the RE market between the years of 2004 and 2015. Current investment trends and indicators of every macroeconomic region, as well as forecasting of future investment volume, may conserve investor resources and promote their investment efforts. At the same time, the work does not advise stock operations intended for gain in the investment margin of RE, since doing so does not conform with the purpose of the research.
- *Start-ups*: This research depicts the most suitable regions to place their business in terms of money allocation from governmental funds and/or business investors. Many countries (e.g. China) have a significant demand of RE projects funded by a greater supply of local venture capitalists, banks and private investors. Potential trade barriers and competitors, as well as concrete names and titles, are not included in current study.
- *Government*: Since in over 100 countries already exist established power policies, the research gives an outlook towards an outcome of these initiatives in terms of investment inflow volume change in various regions. This research attempts to initiate government interest in financially promoting sustainable development by highlighting possible consequences of climate change. The research does not focus on further investigation of policies within any specific country.
- *Independent agencies and media*: The research consists of current data, calculated using secondary resources, such as energy reports of 2016. Updated data drives financial research and any other types of publication on the RE topic. Correlation between investment in power sector and climate change also provides new insight. In addition, comparisons of development may interest the media. However, the work includes only certain alternative power indicators that may not fully depict individual regional conditions.
- *Students*: The project provides easy-available data for assignments, studying or for seeking new career possibilities. Students may find this research as a guide for finding reliable data resources.

- *Society*: The researcher identifies challenges facing the modern world and proposes potential remedies. Top disputes among society are discussed on topics concerning the reality of global warming. The goals of sustainability and social responsibility are promoted by recounting primary causes of present difficulties.

1.5 Structure of the research

The thesis consists of seven chapters, each contributing to the final research objective. The second chapter familiarizes the reader with key concepts of sustainable development. The objective of second chapter is to present an overview of the situation in climate developments and encourage immediate changes. The third chapter describes renewable energy, its place in the energy market and its competitiveness with other forms of power generation. The fourth chapter introduces the financial aspects of alternative power, primarily focusing on investment flows, the scale of renewable power and price factor affecting larger exploitation of renewables. This chapter also presents the reader with existing RE policies favouring business and investment activity in the RE market. The fifth chapter concerns the design of methodology. This chapter defines the methods used in research, data analysis and employed sources.

Answers to the research questions are presented in chapter six. Different methods, characterized in the previous chapter assist the reader for better comprehension of data analysis results, link the methods with the RSs, defined in Section 1.3. The author discusses the patterns that come to the surface. The main focus is devoted to the projections of future investment flow and the development of renewables in a regional scale. The author then connects global warming with historical events of the last hundred years and related energy initiates. In the last chapter, the author concludes with his findings, makes suggestions for future research and talks about social responsibility in environmental protection.

2 SUSTAINABLE DEVELOPMENT AND CLIMATE CHANGE

2.1 The need of sustainable development

The balance between the economic and ecological systems becomes a global challenge in the 21st century. The current changes are just a part of what started back since the Industrial Revolution in the 19th century. The statistics of economic development just in the 20th century, notwithstanding downfalls during crises and World Wars, helps to measure the damage caused by civilization (Ryden, 2010):

- Global population increased 4 times (1.5 → 6 billion)
- Global economy – 14 times
- Energy use grew 16 times
- Industrial production – 40 times
- Agricultural fields became twice bigger
- Number of pigs increased 9 times
- Global fishing catch raised 35 times
- CO_2 emission increased 17 times; SO_2 emission - 13 times
- Deforestation at around 20%

The abovementioned data represented only the 20th century, disregarding overall development during 16 years of the 21st century. This cannot last forever, because there are the limits to growth. In 1972, the Club of Rome, a non-governmental organization comprised famous industrials, political and social doers, emphasized that nature cannot support human life with the rates of economic development and population growth for another 150 years, as published in their breakthrough report *The Limits to Growth* (Meadows, et al., 2004). Later on, commemorating 40th anniversary of *The Limits to Growth*, one of its co-authors made a global forecast for the year 2052. It states that population will continue to grow up until 2040, when the death rate will start to outrange the rate of birth (Randers, 2014). However, even if that scenario occurs, it does not solve the major energy consumption issue and the decreasing volume of hydrocarbons left on this planet (see: Section 2.3).

Nowadays, humanity faces a hard choice described as the global ethical trilemma. Three triangle corners corresponding to three dimensions which are usually used to define the sustainable development: an ecological factor – sustainability, an economic factor – prosperity and a social factor – justice (Eriksson & Andersson, 2010).

The following Figure 1 represents the global ethical trilemma divided into three dimensions, described after Figure 1:

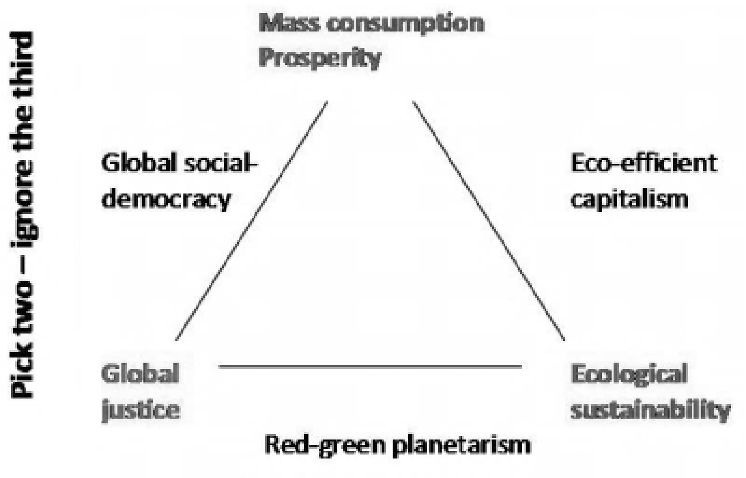


Figure 1. The global ethical trilemma: pick two – ignore the third (Eriksson & Andersson, 2010)

Mass consumption prosperity declares national economic growth as an end goal. The aim of any country is to achieve the highest possible development stage with sufficient welfare of all its citizens. However, the prosperity dimension does not encompass growth limits within the Earth's finite resources and infinite human desires (Eriksson & Andersson, 2010).

Global justice advocates global justice among all mankind. Despite promotion of human rights by organizations such as the United Nations, inequality is still a routine. The basis of global justice places inability to achieve the desired level anywhere, i.e. diverse barriers on a global scale. Money defines an individual's capabilities in a modern world. Yet global integration only increases the abysm between "poor" and "rich" countries in the process of time (Eriksson & Andersson, 2010).

Ecological sustainability promotes ecological maintenance of all species and functional capabilities of the planet in consumer society. It is proven that modern depletion of nature resources is 1,000,000 times faster than its formation time (U.S. Department of Energy, 2013).

The choice taken by the government is what really matters. In deciding on which of these dimensions to focus on, generally at least one is always ignored. 'Global social democracy" stands for the faster progress of developing countries rather than the rich ones. In focusing on "red-green", government has to put justice in front and accept no further growth of the economics (often coupled with progressive taxation form), whilst "eco-efficient capitalism" tends to set the right price for natural resources, ignoring the unequal abilities of its acquisition (Eriksson & Andersson, 2010). We continue to live in a world, where national prosperity dominates the interest of its leaders. In most developed countries, such as Canada, Australia, Germany, Ireland, New Zealand and Netherlands, the justice factor is highly developed in terms of the highest minimum wages and Human Development Index in the world (CNNMoney, 2016), (UNDP, 2015). Hence, it is ubiquitously agreed that the sustainability dimension was of least concern for most of the countries until 1990's.

Recent international agreements created a platform for developing sustainability on a whole new level. Section 2.2 reports the most successful global conventions and its clauses of the last 20 years.

2.2 International conventions to response a climate change

For long-term survival, the world needs to face the green revolution. It all begins and ends in the mind. Ralf Fucks, a famous German politician specializing in sustainable city development and green initiatives, stresses a need for more intensive green politics globally. On its basis, he places mutually advantageous conditions. Governmental help has to stipulate innovation by reducing the tax base. The more exemptions towards sustainability deeds are made in long-term perspective, the more investment is pulled in this desired field . A combination of instruments has to be used: tax credits, gas emission quotas, higher transportation and building standards, funding and acceleration help to start-ups and intensive governmental purchases with an eco-background. That will lead to higher investments in renewables, applying energy efficiency initiatives, usage of ecological technologies that strengthen the sustainable development (Fucks, 2016). At some point, each state will be forced to move to other natural resources and the later it happens, the more expensive it is going to be for the world economy. Global agreements may force the nations to seek alternative solutions. There are not many successful examples regarding efficient global restrictions directed to nature and climate protection, such as Antarctic Treaty System. Even the North Pole may potentially become the subject of natural resources pretension.

More than 100 countries already use different policies in order to diminish extensive usage of FF in several economic sectors: power, transportation, chemical engineering and livestock (REN21, 2016). It's clear that for the effective response to a climate change, countries have to co-operate on an international level. Greenhouse gas emission has no state borders so it freely dispels across the globe. Below are presented some of the prominent conventions that boost sustainable development and encourage the adoption of renewable power technologies:

The United Nations Framework Convention on Climate Change (UNFCCC), international environmental treaty for the main climate action driver, ratified by 197 countries. Under their guidance, annual COPs are assembled to collaborate for the global climate change mitigation. The most successful conferences were held in Kyoto 1997 and Paris 2015.

The Kyoto Protocol was negotiated in 1997 and came into force in 2005. The agreement is binding industrialized countries to reduce greenhouse emission (CO_2, CH_4, N_2O, SF_6, HFC and PFC) by 5.2%, matching the year 1990 (Kyotoprotocol.com, n.d.). Regional targets differ from continent to continent. So far 192 parties ratified The Kyoto Protocol under the UNFCCC.

COP21, the Paris Agreement on climate change, was negotiated in December 2015. The main aim for 195 nations is to keep the global temperature below 2°C and drive efforts to safer defence line of 1.5°C above pre-industrialized levels (UNFCCC, 2015). Every participated nation obliges individual mitigation commitments under intended Nationally Determined Contributions starting from 2020.

Other green politics approaches to climate change mitigation and sustainable development exist on both the regional and national level. The European Emission Trading System (ETS), a “cap and trade system” allows industries to buy emission allowances, at the same time bounding the carbon dioxide emission (European Comission, 2016). These allowances can be, in turn, traded, or used for manufacturing. Another example is the Asia-Pacific Partnership, affecting nearly half of world inhabitants living in this region. Jointly working on sustainability programs, their objectives are to expand markets and investments in cleaner sectors; working on RE projects, advanced transportation, energy efficiency, methane capture by promoting and financing these initiatives (World Nuclear Association, 2016).

There are many more examples of global and local policies, as well as partnerships regulating green-oriented business activities and investments flows. As later discussed, the result of these actions does not fully temper with the process of climate change.

2.3 Power sector – major assailant of changing climate

Rising greenhouse gas emission volume is directly linked with the changing climate. Figure 2 below presents the greenhouse gas concentration (GHG) in the Earth's atmosphere. The level of CO_2 and other gases remained relatively stable until the 1900's. However, during the past 100 years the situation has changed rapidly.

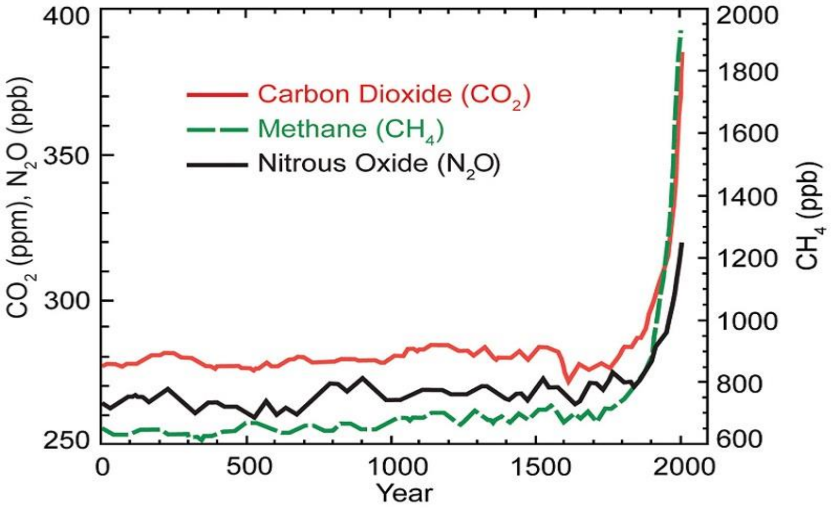


Figure 2. GHG concentration throughout the years (EPA, 2014)

Planet and its inhabitants are encountering high risks from air pollution: the increase of cancer illnesses and other body burden, negative human respiratory system responses, not forgetting the numerous effects on vegetation, animals, materials, atmosphere, soil and the planet itself. The ozone layer is what protects the Earth from radiation. However, ozone holes damage the marine food chain and a variety of crops in the Arctic region. Most importantly, it affects the climate. About half of the light reaching Earth's atmosphere passes through the air and clouds to the surface. In the surface, light absorbs and then radiates upward in the form of infrared heat. 90% of this heat is then absorbed by greenhouse gases and radiated back toward the surface. Humanity extremely increased its levels of GHG emission in the last century, which led to a global warming of the ocean and surface. Life on Earth without the ozone layer would be similar to that on Mars (NASA, 2014).

According to Intergovernmental Panel of Climate Change, the mean sea level, as well as mean temperature, has changed in the past 150 years. Since 1900, the global average sea level has increased on 17-18 cm; the Arctic summer sea ice extent has diminished from 10.7 million km^2 to 6.1 million km^2; and the global average of combined land and ocean surface temperature has changed from ~ -0.4°C to ~ +0.6°C

(IPCC, 2013). Fatal changes are the results of growing population and requirements for their desired living standards. Mass prosperity was taken as a final goal in the 20th century. Environmental and ecological issues started to become of interest only in the late 1960’s. Since then, despite a vast number of research projects and activities, the situation only became worse, as the Figure 2 states.

Increasing GHG emission can be interrelated with a huge power demand, required to sustain the life of over 7.46 billion people (Worldometers, 2016). Power is generated from various natural resources with different GHG emission rates. The figure below presents GHG emission intensity per generated GWh using different sources of power:

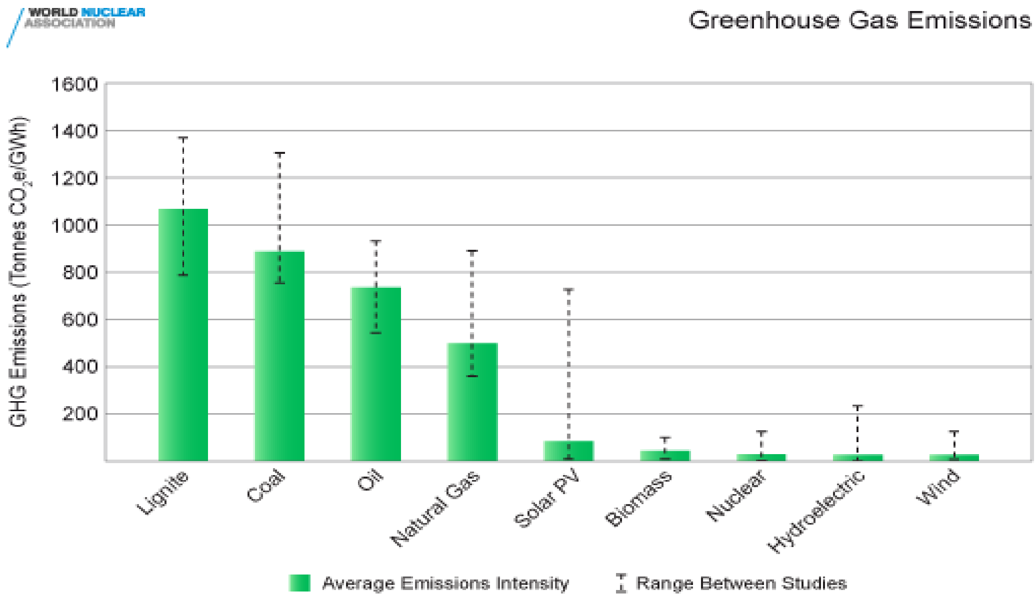


Figure 3. GHG emissions intensity per produced GWh (World Nuclear Association, 2011)

Lignite, coal, oil and natural gas in the aggregate are called fossil fuels, or hydrocarbons. They are exhaustible and, as depicted in Figure 3, pollute air of the Earth. Hydrocarbons generate 86% of world power, the least in electricity power sector ~ 78% (REN21, 2016, pp. 32-33). They are extremely efficient, easier to extract and store, are used in multiple industries. RE power, in turn, is primarily associated with electricity generation with just scarce heating and cooling additions. However, they have sufficient deterrents for sustainable development. Unlike renewables, FF causes much higher GHG emission, based on World Nuclear Association findings. National calamities, like oil spill or mine accidents, result in losses of hundred thousands of lives annually (Mine Safety and Health Administration, 2015). Hydrocarbons are finite and their cost is likely to rise as the time goes.

Hydrocarbons are not likely to last forever. The expected extraction period of proven fossils reserves to current production rates was estimated by British Petroleum:

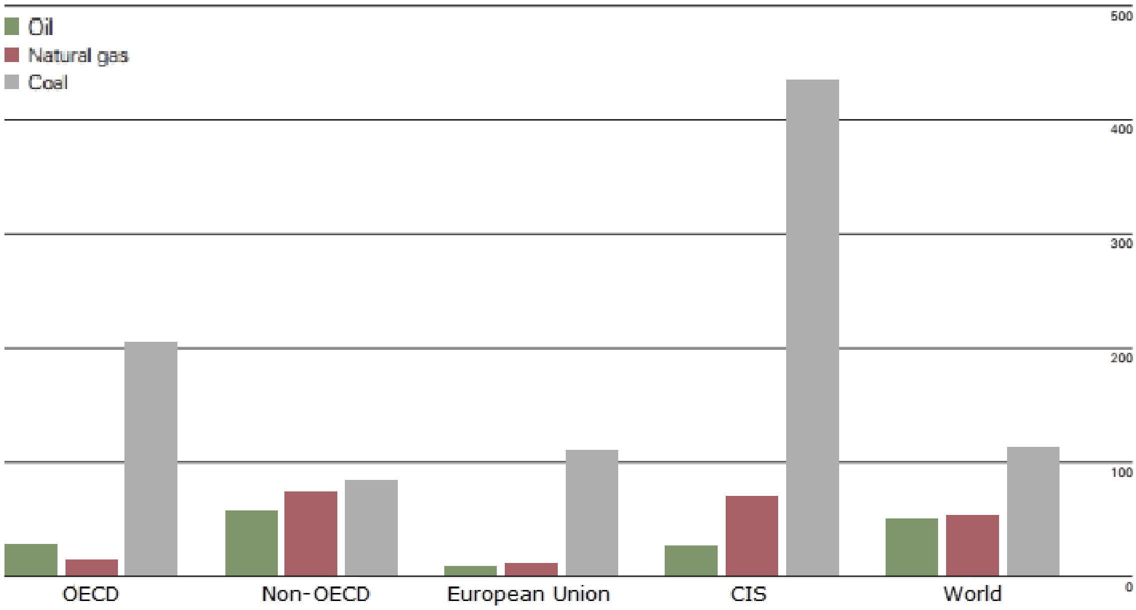


Figure 4. FF reserves-to-production ratios at the end 2015 (British Petroleum, 2016, p. 43)

Figure 4 represents current world and regional reserves of hydrocarbons expressed in years needed to deplete them. Of particular attention is the world reserves-to-production ratio, according to which FF will end by the year 2130. Oil, as well as natural gas, with present consumption rates may last for nearly half a century, whilst coal (including lignite) for only 115 years (British Petroleum, 2016). Sustainable development is not just an option – it is a necessity for a human race and present living standards. The slower the transformation goes, the more expensive it is going to be for every single nation later on. Fossils are not used just for power generation – medicine, cosmetics, science, first need goods, even modern food industry cannot exist without hydrocarbons (VestiFinance, 2014). The faster humanity transforms their energy sector, the more resources will remain to other economic branches.

It is clear that the world needs a different path to diminish the dependency on hydrocarbons. The 21st century presented us renewable energy as a potential solution to diminish the use of hydrocarbons. This form is not new, yet it received a great deal of attention only during the last decade. Next chapter will examine the sources of RE and its potential to become a foundation of sustainable development.

3 RENEWABLE ENERGY OVERVIEW

3.1 Scale of Renewable energy

Renewable energy, as described in Section 1.1, is a non-depletable source of power, the popularity of which continues to grow. It holds considerable potential to replace hydrocarbons in the future. Below are basic descriptions of most common forms of renewable energy, as defined by John A. Matthews (Matthews, 2014):

- *Hydropower* – energy generated from flowing water. Specially constructed dams use flowing water to generate electricity by using turbines. Most widely used among all alternative sources of power, in certain countries, like Norway and Iceland fully meet national power requirements. First hydropower dam was constructed in Northumberland, the United Kingdom in 1878.
- *Geothermal* – heat from the Earth's interior. Energy is obtained by transferring underground heat to the surface using heated groundwater or by pumping water down from the surface. Italian town Landerello is well known due to F. De Landerel's work of building first-ever geothermal power generator in 1904.
- *Solar power* – energy derived from solar radiation in various forms. Photovoltaic (PV) and concentrated solar power plant (CSP) generates electricity when sunlight strikes a solar cell. Considered as the most abundant source of power. The first-ever solar power cell was built by Frank Shuman in 1913, Egypt.
- *Wind energy* – kinetic energy generated from wind turbines (electrical energy) or windmills (mechanical energy). One of the most fast-growing power sectors. First wind turbines were exploited at the end of the 19^{th} century, Denmark.
- *Biomass* - the total weight of living organisms accumulated over time. Organic materials combustion is a RE source since the plants replace themselves.

These are only limited options to generate renewable power sources available to the planet. Tidal energy, wave energy, ocean energy, solar heating and bioenergy (algae growth) are other minor non-depletable natural resources, which produce mechanical, thermal and electrical energy. Nuclear energy is not considered as an RE source of power because of finite reserves of uranium and plutonium. Despite the large list, only 5 forms (sun, water, wind, geothermal and biomass) of RE are largely exploited. Large hydro projects (> 100 MW) are not considered renewable because free-flowing biological systems do not remain as diverse and productive, causing reservoir emissions (Sharpe, 2014).

Changes in power generation request share redistribution towards greater use of other power resources. Hydrocarbons still hold 86% of world energy generation, giving renewables only 2.78% share (excluding large hydropower). The world energy consumption graph between 1990 and 2015 is presented below:

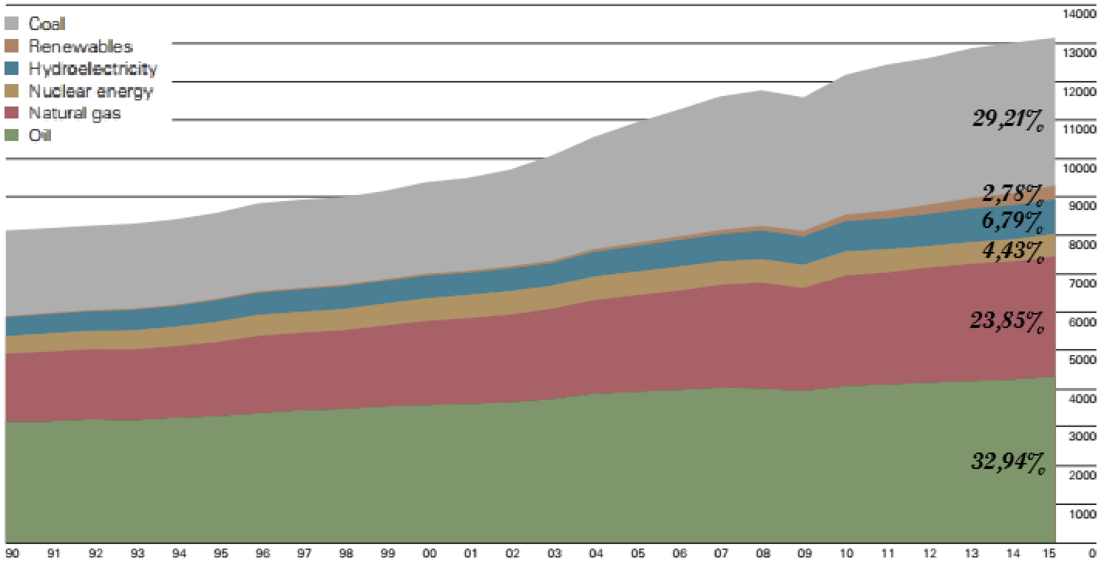


Figure 5. World energy consumption share, 1990-2015, in Mtoe (British Petroleum, 2016, p. 42)

The primary focus of renewables is electrical power. Accordingly, the estimated share in global electricity generation coming from other than hydrocarbons is 23.7%, in which large hydropower holds 16.6%, wind – 3.7%, biomass – 2%, solar 1.2% and geothermal energy with other renewable sources – 0.4% (REN21, 2016, pp. 32-33). Other fields of power, like heat, municipalities, industrial production and transportation are in the realm of fossils. To displace fossil fuels, alternative power generation must become economically profitable. To achieve that, technologies (including maintenance and operating costs) of alternative power generation must be financially competitive to raw fossils. The biggest disadvantage or renewables is electricity generation intermittency and power excess storing. For sustainability of future electric grid the greatest R&D challenges are the cost minimization, as well as prediction of power production and power demand (Fares, 2015).

3.2 Energy Returned on Energy Invested and Levelized Cost of Electricity

The most important characteristics for the world economy is affirming the financial feasibility of renewables and fossils commercialization is EROEI and LCOE ratios:

1. EROEI (EROI) (*Energy Return on Energy Invested*) – The amount of energy that is needed to produce a certain amount of energy. The EROEI is a key

determinant of the price of energy, because the ratio decreases when energy becomes scarcer and more difficult to extract or produce (Investopedia, 2016).

2. LCOE (*Levelized Cost of Electricity*) – LCOE is calculated by summing up all the costs during the lifetime (including production and decommission) of the generating technology divided by the units of energy produced during the lifetime of the project usually accounted in USD/kWh (Dyesol Ltd, 2011).

Financial, legislative, labour, logistics and other local specifics has to be taken into an account then testing the expediency of using certain energy resources. It should be noted that unique design of EROEI and LCOE ratios for each region within the country is key to effective budget planning. The reason is the price of energy, the purchase and decommission of it, as well as all operating costs that differ between the countries and even between the nearby cities. This is why using secondary data can be misleading when working with externally calculated EROEI and LCOE. Clearly, mean ranges are used to depict only the hypothetical scenario of energy costs. But on a global scale it identifies the overall mean projections of all natural resources used for power production. This section concentrates on the selection of the most effective energy technologies used worldwide.

The most recent publication by D. Weißbach of global EROEI, presented by Forbes, illustrates the mean global ratio for every technology used to generate power:

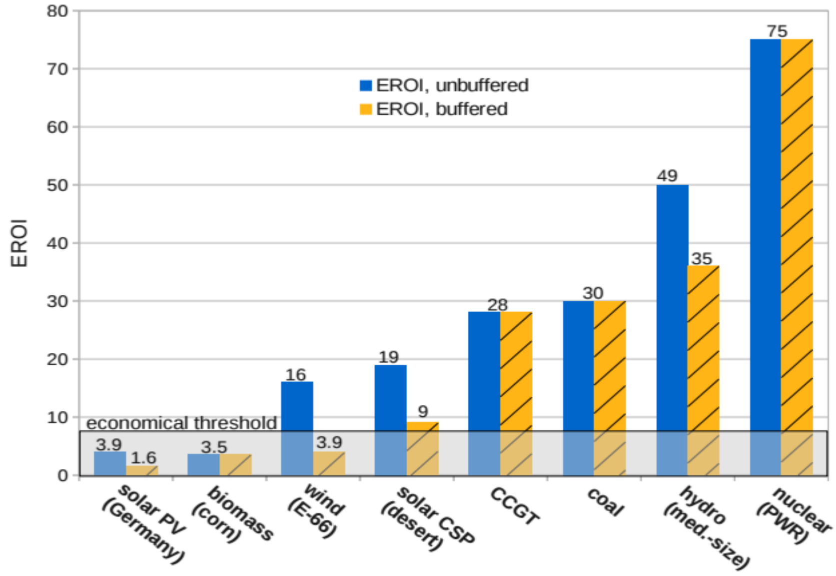


Figure 6. Global EROEI of all energy techniques with economic "threshold" (D. Weißbach, 2013)

Figure 6 depicts favourable present conditions for fossil fuels extraction. The greatest advantage of hydrocarbons is that energy storage is cost effective due to fossils long-term storing potential, meaning that they are burned only when it is needed. On the other hand, renewable energy not only loses a certain percentage of energy for transmitting and storing electricity on the grid, but also additional energy is required to store the generated power from other renewable technologies. The buffered EROEI accounts energy storage factor – due to this approximately twice less energy can be generated from solar cells (PV and CSP); four times less from wind turbines and in the case of hydropower - 1.4 times less. PV solar panels are mostly used in the private sector (rooftops) to meet family households own needs, albeit EROEI equalled four still does not meet break-even number, which is seven (D. Weißbach, 2013). In his statement, James Conca believes that, in order to adequately fuel our modern society, the EROEI break-even number must be equal to seven. He also states that countries with higher EROEI have great potential for economic expansion and energy diversification, which may result in cutting carbon emission and entering a cleaner future (Conca, 2015).

Figure 6 lacks the EROEI ratios of oil and other minor FF resources. According to Hall et al., oil EROEI dropped dramatically during last decades and had a mean of 20:1 by the end of 2012. Oil shale has a mean of 7:1, whereas tar sands only 4:1 (Charles A.S. Hall, 2014). It has to be reminded that EROEI is an unstable ratio, which changes over time. If fossil fuels tend to diminish, renewables remain steady and potentially are likely to increase in case of technological improvements. The upcoming recession of the hydrocarbons EROEI ratio was obvious 100 years ago to J. Paul Getty, an industrialist and oil magnate. In the 20th century, when hydrocarbons EROEI was as high as 100, only large hydropower could economically compete with FF (Carroll, 2015).

The global LCOE, as estimated in 2013 by Bloomberg New Energy Finance, is illustrated in Figure 7. This figure represents the range of costs needed to produce 1 MWh of the electricity in USD depending on power generation technology. The less the range and central (mean) price are, the more financially feasible it is to generate power from particular technologies, including all previously mentioned lifetime costs. LCOE price is used to compare economic effectiveness of different power generating resources. The cost of finance differs between employed technologies, economic-political risks and peculiar locational properties around power facilities.

Figure 7 shows broad differentiation between existing power supply technologies. Again one observes greater economic advantages of hydrocarbons and nuclear power. Hydropower is the only source proven effective with the LCOE price below 10 US cent per produced kWh. Nevertheless, enhancement of national policies such as FIT, net metering and tendering impressively dropped the price of LCOE for renewables.

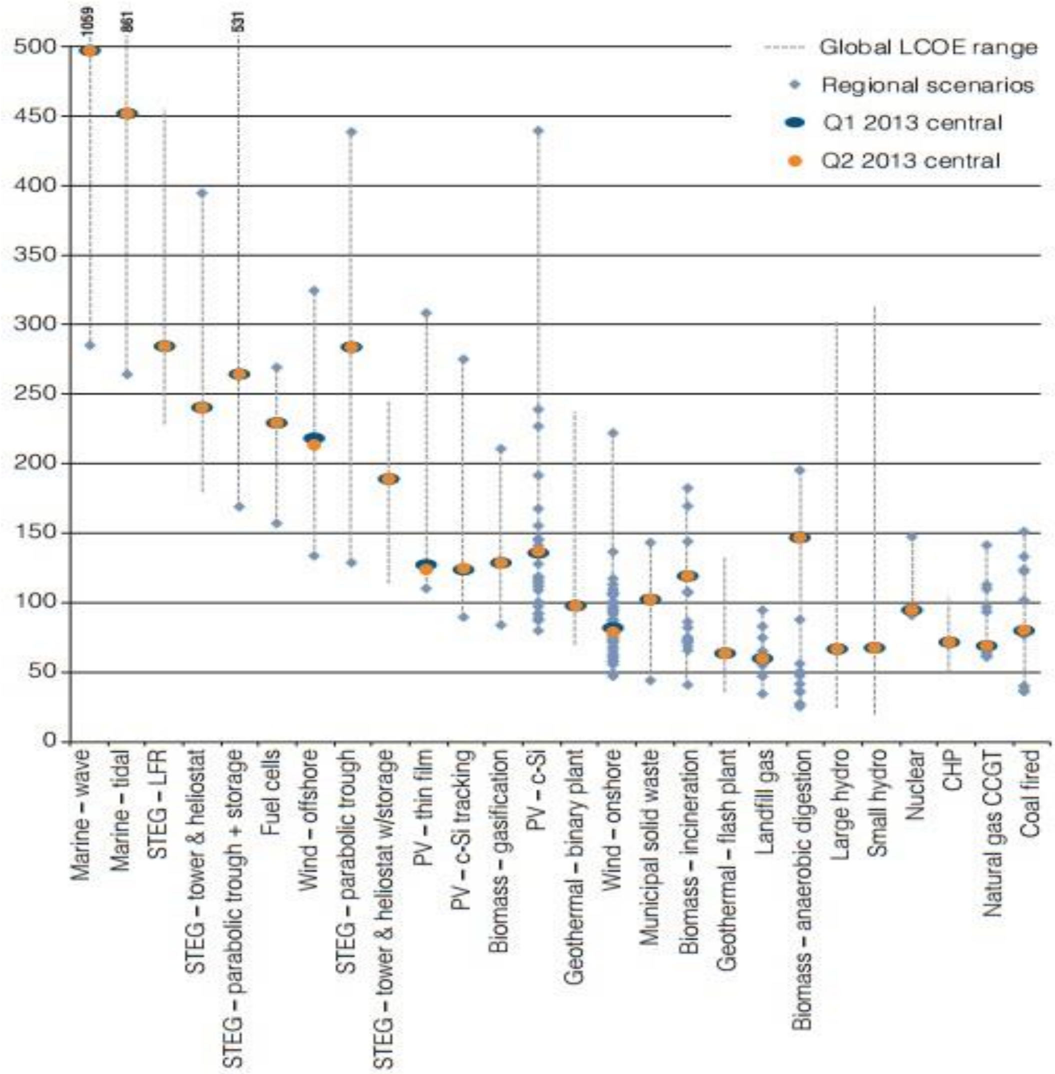


Figure 7. Global LCOE range in 2013 by Bloomberg USD/MWh (World Energy Council, 2014)

3.3 Levelized cost of electricity in regions

Section *3.2* underlined the EROEI and LCOE cost differences between different forms of RE technologies. However, these do not necessarily suggest that these estimations are veridical at every region around the globe. Taxation, installation, maintenance and other operating costs naturally differ between countries, as varies the abundance of mineral reserves between the regions. Selecting potential markets for business of investment requires throughout investment climate analysis. This consists of not only calculating labour, taxation and other economic factors, but also concerning local peculiarities such as social acceptance, geographical location, infrastructure and other incentives affecting business activities.

Figure 9 presents the typical LCOE averages of the main forms of renewable power generation based on global macroeconomic regions:

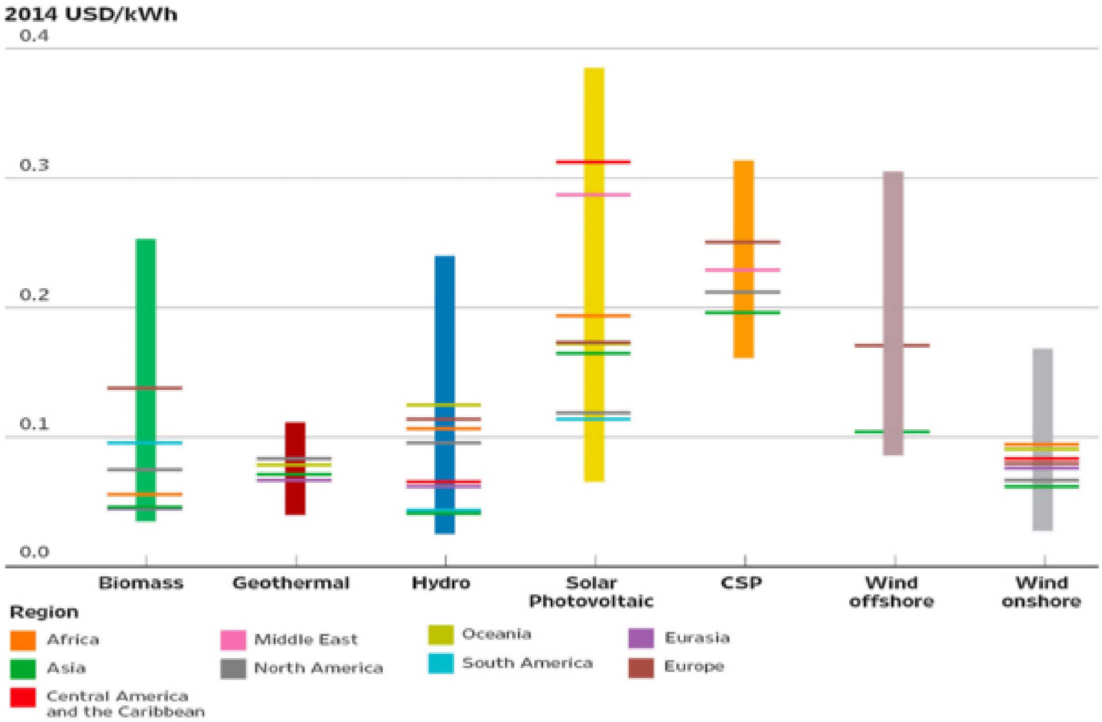


Figure 8. LCOE and regional weighted averages by technology (IRENA, 2014)

The break-even (LCOE) price is adjusted by electricity demand, net capacity of energy sources and RE policies. Solar PV price per produced kWh is lower in Europe and North America than in more suitable regions in terms of solar radiation and labour costs. For example, Germany has contributed heavily to the larger adoption of sun and wind energy, which resulted in powering the whole national electricity demand from renewable sources of power on May 8 of 2016 – commercial customers were being paid to consume electricity for almost 6 hours (Coren, 2016). Other European countries, like Denmark, the Netherlands and Belgium also aim to follow German's success. As shown in Figure 9, in North America almost all electricity generated from renewable sources (expect for solar) are of the less price than 0.10 USD/kWh. Detection of this presumes that geographical location is not the key factor for RE commercialization, as are the investments in R&D and renewable assets. Although advanced countries are usually recognized as the most polluting ones, they also tend to create new trends for sustainable development exaltation.

3.4 Pros and cons of existent power sources

The table below represents the summary of the advantages and disadvantages of existent power generation technologies, based on numerous publications:

Table 1: Advantages and Disadvantages of the most common sources of energy

	Advantages	Disadvantages
Coal	• Cheap and affordable • Versatile and reliable • High energy efficiency • Abundant (>100 years) • Easy to burn • Not dependent on weather conditions • Easy to transport • Create a lot of workplaces	• CO_2 emission • Ecologically unfriendly: deforestation, soil pollution and acid rain • Coal mining ruins the environment • Considered finite with current level of consumption • Hazardous and dangerous to miners • Non-sustainable
Oil	• Key to today's world economy • High energy density • Easy to extract, store and transport • Reliable and constant source of power • Main fuel for vehicles • Used in broad number of industries (food, medicine, cosmetics and etc.) • Current favourable price of oil	• Air pollution through the greenhouse gas and other harmful gases emission • Water and Earth pollution • Finite and non-sustainable • Component of many toxic materials • Dramatic consequences of potential tanker oil spill • Potential price increase
Gas	• Easy to transport, distribute and store • Used at residential and transportation • Safe storage below the ground • Less harmful among all hydrocarbons • Abundant and economically feasible • Continuous power supply source • Broadly used in a set of industries	• Expensive installation costs • Toxic, flammable • Non-renewable • Environmental damage – immense GHG and other gases emission • Expensive process of pipeline construction
Nuclear	• No GHG emission • High energy return • Reliability • Output control • Low expense to produce and transport • Sustainable – does not affect climate change • More proficient than fossil fuels	• Radiation release • Water pollution when cooling • Expensive waste disposal • Leaks and tragic accidents • Decommissioning is a long process • Uranium is unstable element • Shutdown of reactors consequences • Subject of military interest
Solar	• Renewable source of power • Free and abundant • Solar generation is clean • Can be installed at residential rooftops • Relatively easy installation process • Little maintenance needed • The largest energy capacity potential • Low initial costs to other power installations	• Relied on weather conditions • Much space needed • Challenges associated with energy storages • Damaging the wildlife because of the heat coming from the solar cells • Surface heating • Manufacturing solar cells is extremely polluting process • Solar cells can be easily damaged

Hydropower	• Constant energy supply, as dam is built • Last for decades • Low cost of electricity • No greenhouse gas emission • Flexible: dam work can be stopped • Energy can be stored until needed • No waste and pollution • Recreational and sport places are built behind the dams • Large efficiency of a single dam	• Expensive building • Large areas flooding • Natural environment destruction – both for aqua life and wildlife animals • Forced migration of locals • Agricultural problems (soil) • Limited places to build reservoirs • Energy shortages when drought • Conflicts between countries when drainage basin crosses the border
Wind	• Renewable and sustainable • Small plot of land needed • Generation doesn't emit any GHG • Can be used for both industrial and domestic (private) use • Low installation, maintenance and running costs – cost effective • Free source of power • Large powering potential	• Noise pollution • Low power capacity of a single wind turbine • Wildlife (birds) are killed • Power supply is not constant • Sometimes socially unacceptable in terms of aesthetics • Power transmission to living areas • Sometimes not profitable use of land
Geothermal	• Renewable • Low maintenance costs • High return from the small area • Environmental friendly, no waste • Not dependent on weather conditions • Can be used directly • Abundant supply	• Usually located far from the cities • High installation costs • Possible release of harmful gases from the holes • Danger because of the act of god • Geothermal pump has to be powered • Cost effective only in limited regions • Small generation capacity potential
Biomass	• Renewable and abundant • Initiates cleanliness • My be used to create goods • Easy accessible • Reduce amount of waste landfills • Considered reliable • No GHG emission	• Expensive energy source • Less efficient than hydrocarbons • Much biomass fuel need to produce biomass energy • Expensive equipment costs • Spread of pests, unwanted infections • Seasonal (when crops are used) • Methane emission

Based on articles gathered from: (Technology Student, n.d.), (Green World Investor, n.d.), (Converse Energy Future, n.d.), (Fossilfuel.co.uk, n.d.), (Occupy Theory, n.d.), (Energy Informative, n.d.).

As demonstrated in Table 1, alternative power possesses as much drawbacks as other power sources. The focus of this work is climate change mitigation by commercializing RE as a form to sustainable development. Future generations will have no choice but to use renewables and its foundation must be established in the present. A vast volume of investment is already allocated in the RE market. The next chapter provides more details of recent global cash inflow in renewable assets.

4 INVESTMENT TRENDS IN RE SECTOR IN 2016

4.1 Investment volume by regions

The rapid growth of renewable power commercialization continues since early 2000's. In 2015 a new investment volume record was set in the RE market sector – 286 billion USD. Solar and wind projects allocated the most part of financial resources in that year. China became the new investment leader with the highest net capacity additions in hydropower, solar and wind projects. Because of countries like China, India and Brazil, the investment volume by developing economies transcended the developed ones for the first time in the recorded history (FS-UNEP, 2016, p. 14). This was anticipated due to larger electricity demand in developing countries. Only 4 developed economies remained among top 10 global renewable power investors – the USA, the United Kingdom, Japan and Germany. In the past 12 years, the amount of investment in the alternative resources has already exceeded 2.3 trillion USD.

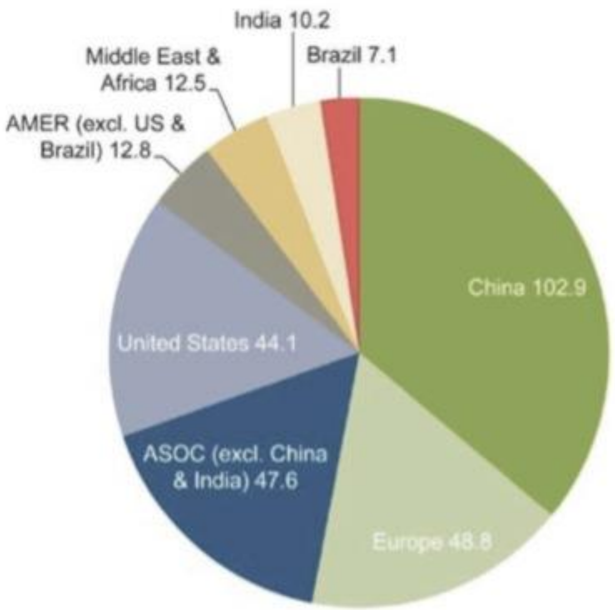


Figure 9. Global new investments by region in 2015, in billion USD (FS-UNEP, 2016, p. 22)

Among developed economies, the USA is considered the largest individual investor, because Germany has experienced a significant drop of investment volume in the past few years. China is the largest investment grandee, contributing into RE projects 102.9 billion USD in 2015. Japan allocated 76% of RE assets from the Asian-Pacific region. Other countries, like the UK, India as well as Africa and Middle East Region saw a considerable growth of RE investment in 2015 (REN21, 2016, pp. 101-102).

Another important incentive that stipulates initiating business in renewable sector is its benevolent power policies. Typical conventional policies of pushing forward renewables are explored in the following section.

4.2 Existing RE policies

Section 2.2 described international conventions regulating global green politics. In renewables, several main types of power support policy mechanisms are recognized:

1. Feed-In Tariff: A legal process where distribution utilities are obliged to purchase electricity generated from renewable facilities meeting specific criteria. Fixed minimum tariffs are guaranteed over a relatively long period (usually between 15 and 20 years) (Wamukonya, 2005).
2. Renewable Portfolio Standards and Quotas: Obligates designated parties to meet minimum renewable energy targets, generally expressed as percentages of total supplies of as an amount of RE capacity, with costs borne by consumers (IRENA Policy Brief, 2012).
3. Net Metering: A billing system that allows electric customers to sell to their electric utility any excess electricity generated. Most commonly used with solar rooftops installations (EEI, 2016).
4. Competitive bidding: A set amount of renewable energy supply or capacity, used in large-scale technologies with high technological risk. Exist in forms of auctions and tenders (ITP report, 2014).
5. Fiscal Incentives: Governmental support expressed in specific forms: grants, rebates, tax credits, tax reduction/exemptions, energy production payments.
6. Public Finance: Involves public support from banks, enterprises and individuals in forms of investments, guarantees, loans and public procurement.

Out of 147 countries that provided power policy data, RE policies are present in 114 countries. 81 countries set their FIT policy mechanisms, 70% of which are from the high and upper-middle income class economies. Net metering exist in 52 countries, competitive bidding - in 64 economies (REN21, 2016, pp. 112-121). Other forms of renewable support policies are also present. Fiscal incentives at any form can be met in 82.3% countries (capital funds – 40.1%, tax credits – 29.9%, tax reduction – 68%, energy production payments – 16.5%). Public finance is present in 57.1% of countries.

Power policies play a vital role in determining the investor interests in alternative power technologies. Many forms of policy mechanisms are still unavailable in developing, low-income economies. COP21 acknowledged the need to promote an universal access to sustainable energy in developing countries through the enhanced deployment of renewable energy (UNFCCC, 2015). It is expected to see positive, auspicious investment conditions for start-ups and investors to exploit developing countries in the next couple of years. RE as an asset financing product is examined in Section 4.4.

4.3 RE as an opportunity for business and investing

The net power generating capacity added in 2015 by contributing money in renewables equalled 156 GW (including large hydropower projects), whilst coal added 42 GW, gas – 40 GW, nuclear – 15 GW (FS-UNEP, 2016, p. 31). The gross investments in renewable energy are approximately twice that of fossils (excluding large hydropower). In relation to other forms of energy resources, investments in renewables continue to grow (see: Figure 10).

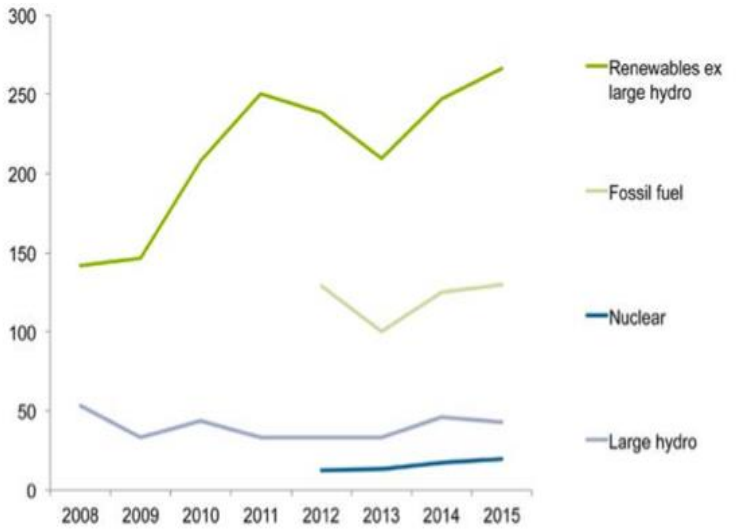


Figure 10. Investment in power capacity, billion USD (FS-UNEP, 2016, p. 32)

For investors, the Return on Investment ratio and stock market personal upsides are important. The top alternative energy index – RENIXX-World, consists of Top-30 stocks with a broad spectrum of activities in the RE sector, such as First Solar, Solar City, Gamesa and etc.

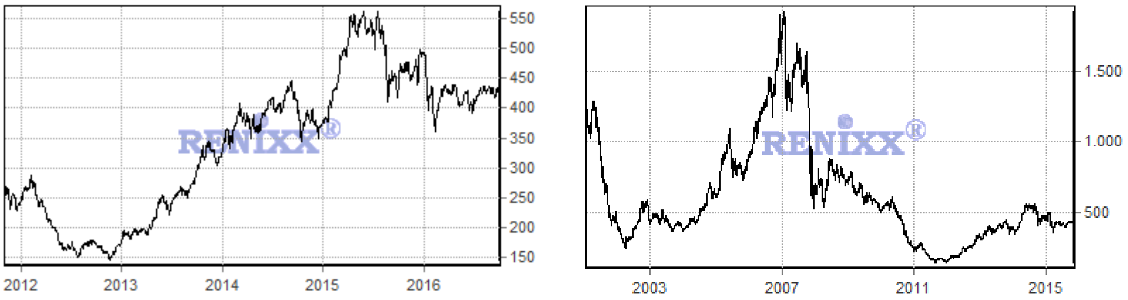


Figure 11. RENIXX World index 5-year and All-time stocks chart (IWR, 2016)

As shown in Figure 11, friendly economic conditions are required for a long-term rise of RENIXX World index. During the 2008 world crisis, RENIXX World index experienced downfall, reaching the lowest point in July 2012. But with the economy recovering, the index started to increase with relative stagnation in 2016. Stock market behaviour during The Great Recession compels attention. It states that, during emergency times, sustainable development and world ecology become secondary considerations. Investment volume in alternative power only rises if given a surplus of capital and asset resources. Economic recovery is interrelated with Gross Domestic Product, which symbolizes increasing employment rate and development of industries. Therefore we need more power for recovery of the world economy. This potentially leads towards a vicious circle, in which for enhanced deployment of renewable power, world economy must produce more energy and leave nuclear and hydrocarbons as an incentive. Can humanity expect the drop of interest to alternative energy sources in future because of another cyclical crisis or growing military tension? Is it so, that the only chance to prevent climate change is internationally united peaceful economy? Whatever the truth of the matter is, that is a good food for thought.

4.4 Other trends in renewable energy

Shifting to green became feasible starting from 2000. Major challenges to sustainability are caused by intensive exertion of fossils - soil loss, deforestation, industrial emissions and ecosystem destruction (Hart, 2007). Investing and doing business in alternative power can diversify and potentially mitigate natural and climate risks. The growing level of environmental awareness has picked up momentum in the past decade – society thinks of the cleanliness of air they breathe, the bin they toss their garbage in, pay more attention to environmental conditions and corporate donations directed to the environmental initiatives through different media channels. (Cohen, 2015). In a mixed economy, the word “environmental” became an attractive tool for obtaining the interest from the side of a customer and is supported on a corporate and governmental too.

Another explicit tendency is a growing renewable concern by emerging economies. The energy demand in China has sky-rocketed recently. In past 12 years China added approximately 3.5% renewable consumption of its overall primary energy consumption. As to that, an objective to reach 15% (in 2015 – 10.1%) electricity production from renewables by 2020 source will require serious efforts in the next 5 years (Sang-Bing Tsai a, 2016). This affords an insight into the continuous rising global trend of energy development coming from the emerging economies in the near future. Other countries, like Japan, Brazil, the USA, India and African region, share common similarities.

In the next chapters, the author selects suitable regions for investment based on statistical methods. Chapter 5 defines the methodology used to conduct statistical analysis based on historical data. Chapter 6 presents the research results.

5 METHODOLOGY

5.1 Investment statistical data analysis

5.1.1 Diachronic Analysis

Diachronic analysis is a study of change in a phenomenon over time (Chandler & Munday, 2011). Diachronic analysis is an analysis of changes in the structure of a specific object over time periods. As a statistical method, it is used to observe absolute and/or relative changes that have taken place within a certain object identify common patterns inside the structure. The aim of this method is to show a broader picture of occurred historical changes that may aid in finding a basis for present trends.

This method is designed to contribute to the first objective of this research - **RS**a. The data from UNEP/BNEF report was used to analyse the changes in the structure of investments in different forms of RE over the past dozen years (2004-2015).

5.1.2 Compound Annual Growth Rate Analysis

The compound annual growth rate (CAGR) is the mean annual growth rate of an investment over a specific period of time longer than one year (Investopedia, 2016). The compound annual growth rate can be evaluated for any kind of investment, but does not include any measure of the overall risk involved in the investment, as calculated by the volatility of it price (ReadyRatios, n.d.).

In this research, the data of investments inflow by economy was used to analyse the CAGR based on global macroeconomic regions. Same as diachronic analysis, it is earmarked to **RS**a. For accurate CAGR analysis of the following zones (Europe; Americas; the USA; China and India; Africa and Middle East; Asia, Australia and Pacific region), CAGR calculations were executed between the years 2004 and 2015. The steps for calculating CAGR are described in *Appendix (1) 1*.

5.2 Forecasting Analysis

5.2.1 Linear Regression Analysis

Linear regression analysis (LRA) is a branch of mathematical statistics dedicated to methods of finding dependence between two or more values. LRA is used when dependence of one value to the other one can be approximated with linear function. Formulas to project future investment flow can be found in *Appendix (1) 1*.

This work used UNEP & Bloomberg New Energy Finance data regarding global investment flow of the past 12 years. Countries were divided in two major groups based on their stage of the economy – OECD were compared with developing and emerging ones. As a scientific method, is assisted in reaching **RS**b thesis target.

5.2.2 Extrapolating a Moving Average Analysis

This forecasting method is applied in cases where available data of the dynamic series do not reveal any trend of a process due to random fluctuations. Extrapolating a moving average analysis (EMA) replaces actual levels of dynamic series with the calculated ones, which, in turn, are characterized by significantly lower volatility than the original data. Required steps are presented in *Appendix (1) 2*.

To forecast a global investment volume through EMA analysis, the researcher used the same criteria as for LRA method (Section 5.2.1), contributing to the same goal **– RS**b.

5.3 Climate change statistical data analysis

5.3.1 The Probability Theory

The probability theory is the analysis of random phenomena. The classical definition – the probability of an event is the number of outcomes favourable to the event, divided by the total number of outcomes, where all outcomes are equally likely (Ash, 2008). Seek out *Appendix 1 (2)* for classic probability equation.

NASA Global Climate Change has been publishing global land-ocean annual mean temperature since 1880. The goal of this research is to calculate the chance of average annual the global surface temperature increase in 2016 to the year 2015, relying on the historical data of the past 136 years. This method is linked with **RS**c.

5.3.2 Comparative Analysis

Comparative analysis is a scientific method that involves one entity or piece of data, and comparing it with others to identify similarities or differences. Comparison can take place between different entities, such as individuals, interviews, statements, settings, themes, or at different point in time. By isolating these aspects, it is then possible to develop a conceptual model of the possible relations between entities (Given, 2008).

The aim of comparative analysis is finding a link between world energy consumption to CO_2 emission – **RS**c. The data of 2004 is taken as basis by calculating the relative increase of the upcoming years. Executed steps can be found in *Appendix (1) 2*.

6 DATA ANALYSIS

6.1 Structure of the investments

Annual investments in the renewable energy market were used to execute diachronic analysis. Five main renewable sources are depicted in Figure 12: solar PV and CSP solar power projects, energy generated from wind turbines, low and medium scale hydropower stations (excluding hydropower projects > 100 MW), geothermal energy and bio – the sum of assets directed to biomass and biofuels installations.

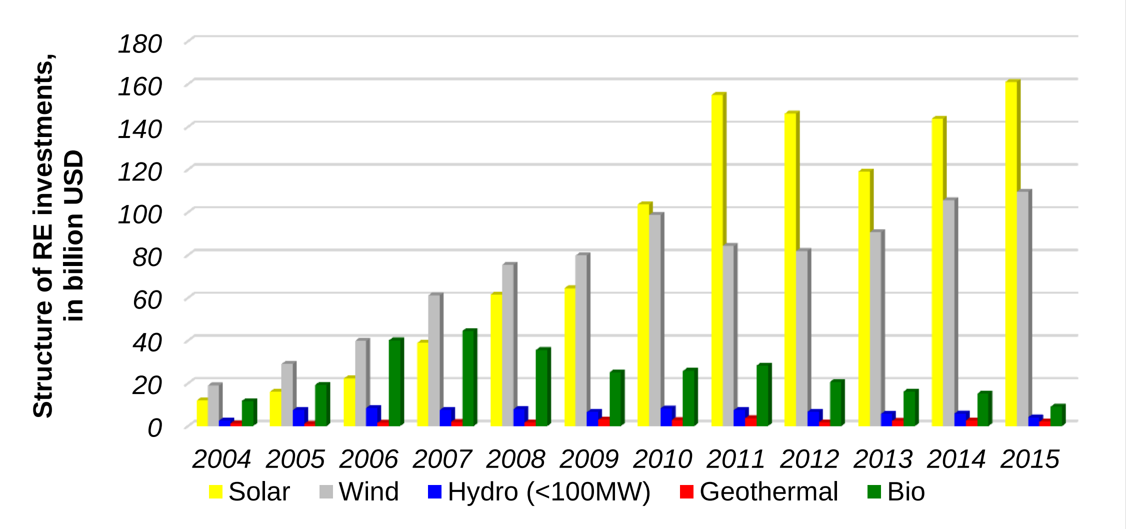
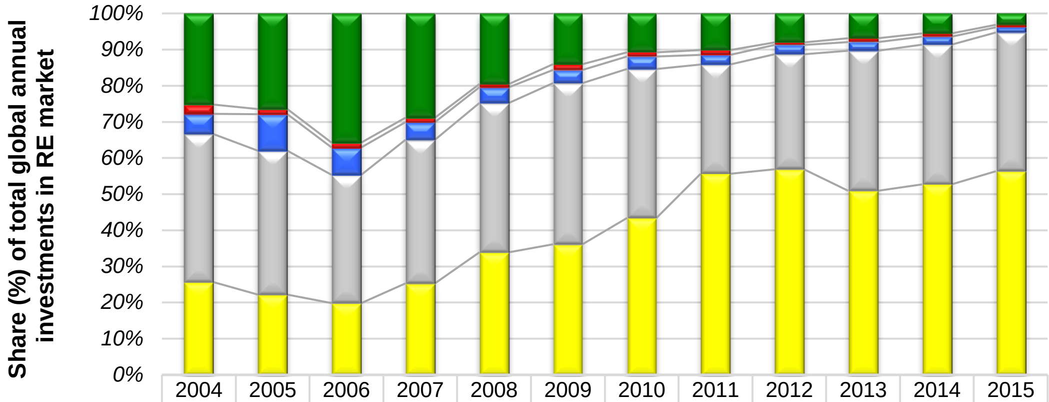


Figure 12. Annual investment in different forms of RE sources (FS-UNEP, 2016, p. 14)

Basic information provided by UNEP aids in tracing the tendencies of growing popularity of solar and wind alternative technologies - +12% and +4% increase to the year 2014 respectively. Bio is currently facing the loss of interest by investors (-42%) to 2014; investments in hydropower and geothermal energy remain stagnant with low volatility during the last decade. Developed countries play a leading role in financing solar assets, whereas wind turbines increase is mainly associated with cash allocated by the developing and emerging economies (REN21, 2016, pp. 103-104). Noteworthy to mention that the large scale hydropower projects investment volume (as illustrated in Figure 10) is not taken into an account due it not meeting the sustainability criteria, leaving these cash inflow aside of this research. A basic assumption of the author states the rising annual RE investment share, allocated in solar and wind power projects, simply relying on higher absolute volume values.

Figure 13 presents the results of diachronic analysis *(method 5.1.1)*, which was carried out through the use of the secondary data, presented in Figure 12. The biggest advantage of this statistical method is the opportunity to look into the same group of data from the different point of view. Diachronic analysis permits the author to conduct calculations of structural changes of equity investments through the prism of time.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bio	25.22%	26.51%	35.77%	28.90%	19.55%	14.05%	10.79%	10.16%	8.05%	6.92%	5.53%	3.18%
Geothermal	2.59%	1.37%	1.34%	1.23%	0.93%	1.62%	1.17%	1.33%	0.70%	1.03%	0.95%	0.70%
Hydro (<100MW)	5.60%	10.16%	7.58%	4.87%	4.28%	3.64%	3.43%	2.69%	2.60%	2.44%	2.16%	1.43%
Wind	40.95%	39.84%	35.50%	39.74%	41.41%	44.66%	41.26%	30.23%	31.83%	38.72%	38.70%	38.35%
Solar	25.65%	22.12%	19.80%	25.26%	33.83%	36.04%	43.35%	55.58%	56.82%	50.90%	52.65%	56.33%

Solar Wind Hydro (<100MW) Geothermal Bio

Figure 13. Diachronic analysis of investments in different types of renewable power sources

Diachronic analysis contributes to a better comprehension of the direction of global investments in alternative power. Several consistent trend patterns are observed. Investors tend to trust and invest more in solar energetics – starting from 2004 (25.65%) annual investment share among all RE sources doubles its size, reaching 56.33% in 2015. More than a half of global renewable assets were permanently directed towards the solar market since 2011. Investment volume in wind turbines grew as well, albeit the share of it remained relatively stable - ~38–42% with a slight share downfall in the period 2011–2012. Conversely, biomass and biofuel projects faced interest loss, as the annual cash inflow share of which in past ten years experienced a significant drop from 35.5% to 3.18%. Low and medium scale hydropower and geothermal power stations remained unpopular, aggravating its share to 1.43% and 0.7% respectively. In the aggregate, wind and solar power projects continued to hold an overwhelming dominance of renewable investment, setting an absolute record equalling 94.68% of share in 2015. In spite of the worst LCOE mean of solar power among all renewables, its popularity continues to grow. Several factors determine the investment behaviour switch to wind and solar energy.

Vast initial investments needed to establish hydropower, geothermal and biomass power stations exclude an opportunity to involve private sector cash. Many hands make a light work – 61% (or 241 billion USD) of global climate financed money came from the private sector in 2014 (Climate Policy Initiative, 2016). Needless to say that private sector, in most cases, can only afford inexpensive RE technologies, leaving wind and solar as the only available options. The research of the author on renewable energy policies during his internship at Masar indicated that the most of FIT and net metering programs are linked with solar and wind electricity, by means of the more advantageous electrical power selling price than that of biomass, geothermal power and hydropower produced electricity. This stipulates the larger adoption of solar CSP and PV – not forgetting that the last type can be placed at residential rooftops. Therefore, this method served in responding to **RQ**1 and partially solving **RQ**3.

6.2 Regional allocation of the investments

The data of the regional annual cash allocation obtained from UNEP was used to calculate CAGR of the following six macroeconomic regions: Americas – South and North American countries (excl. the USA); the USA; Africa and Middle East area; Europe; China and India; Asia, Australia and Pacific region (excl. China and India).

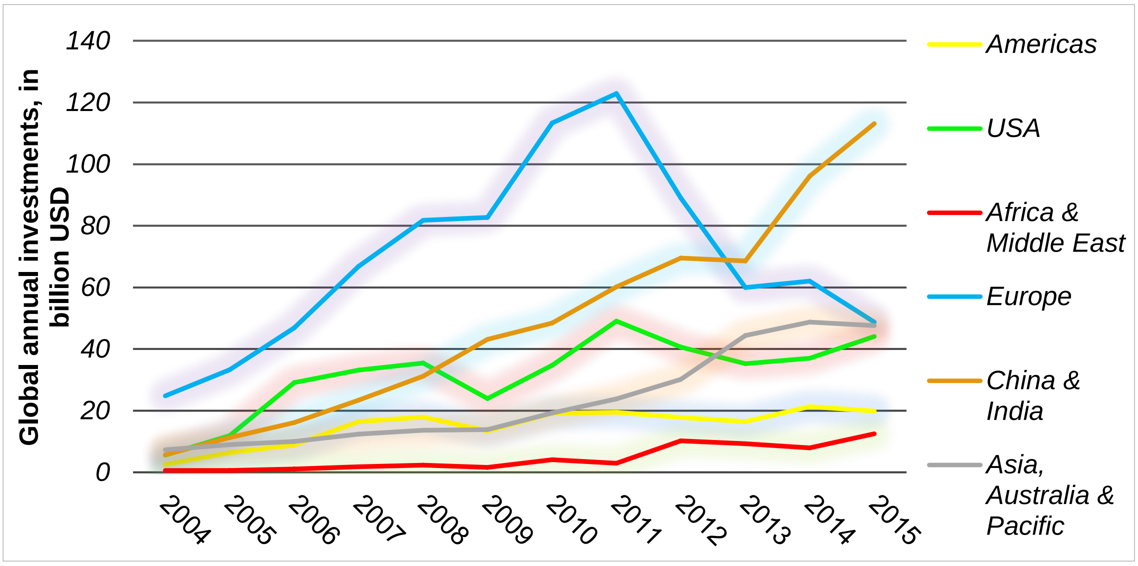


Figure 14. Global annual investment in RE by macroeconomic regions (FS-UNEP, 2016, p. 14)

Figure 14 represents regional global investments in alternative power throughout past 12 years. All the represented global regions are currently experiencing investment growth but Europe, which faces an abrupt downfall since 2012. The reason for this is that in major European renewable promoters, such as Germany, Denmark and Italy, the RE policy framework has changed, in turn resulting in partial interest loss from these countries. The new largest investor appear in emerging economies – China, India and Brazil, the last of which allocated around 47.2% of all investments coming from Americas (excl. the USA) during the past twelve years. China's contribution to financing RE assets has reached 102.9 billion USD in 2015, which makes them the most aggressive RE investor around the world (FS-UNEP, 2016, p. 14). Africa and Middle East, possessing ideal geolocations for planting solar cells and wind turbines, started holding a certain role in cash allocation. Unlike Europe, the regions of Asia, Australia and Pacific continue to have a positive investment trend line, almost reaching the total inflow mark of Europe in the year 2015. However, three-fourths of this volume comes from Japan. The results of the research are delivered in Figure 15, which reflects regional CAGR *(method 5.1.2)*, based on the historical data of Figure 14.

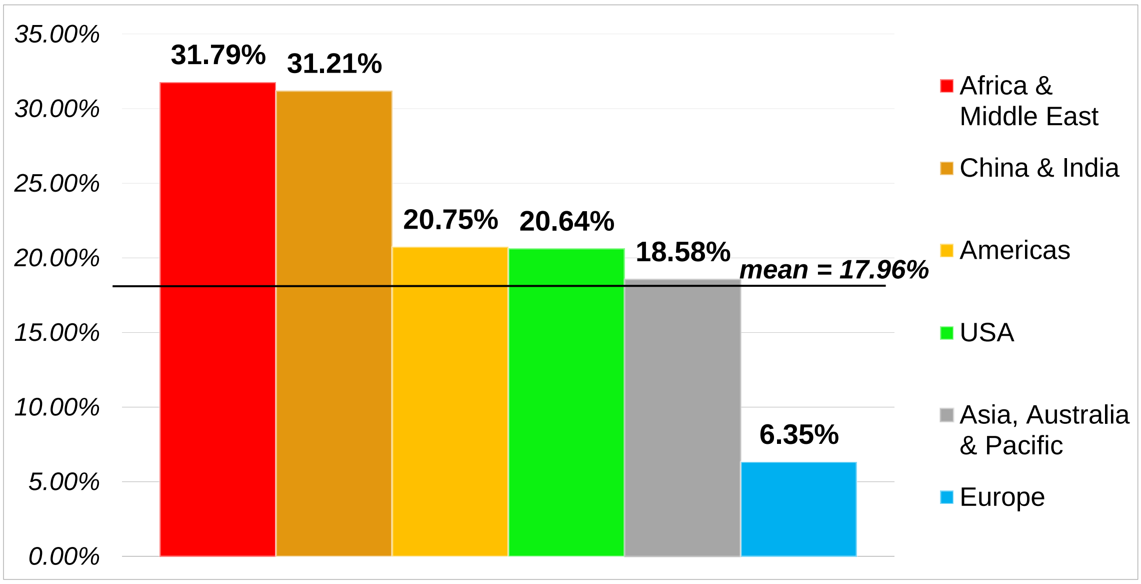


Figure 15. Compound annual investments growth rate analysis of by regions

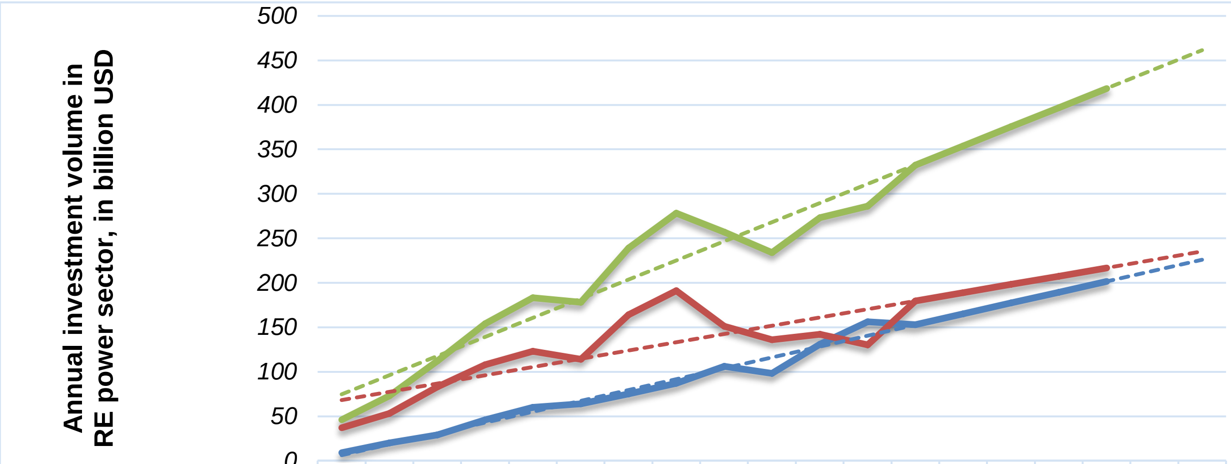
Compound annual growth rate analysis identified the most fast growing economies in terms of RE asset financing. Leading positions belong to developing regions, such as Africa and Middle East, China and India, with the most intensive growth rates – 31.79% and 31.21% respectively. It is too early to measure the contribution from Africa and Middle East area, as in the first analysing years their investment volume in renewable power was petty and consequently led to these high CAGR rates. Europe was the biggest allocator of RE for nearly a decade due to countries like Germany, Italy, the Netherlands and the United Kingdom. The volume coming from European countries was firmly over 44% up until 2011. With relatively low indicators, Europe still has positive CAGR dynamics and remains as the second largest depositor. China's superior position is also affirmed by their CAGR of 37.9%. Out of all the developed economies, the USA has the highest CAGR, which is the result of investing in R&D and innovation by the government and large corporations like L. Rive's & E. Musk's Solar City.

Figures 14 and Figure 15 give diverse representation of investment flows. Europe is still the second largest alternative power contributor, but due to analysis it cannot be named as a fast growing simply because its actual investment continuously decreases. Quite contrary is Africa and Middle East – with relatively low investment capacity the region grows faster than any other. In finding a link between executed CAGR analysis and **RQ**1 & **RQ**2, it becomes clear that every single region has a positive CAGR dynamics, which leads to a larger exploitation of renewables globally.

6.3 Forecasting projections

This part of the research focuses on representing a future flow forecast for five years in the RE power sector (**RQ**1 & **RQ**3). The objects of the analysis are countries as undergoing their economic stages of development. The results are presented in Figures 16, 17 and 18. The primary data is identical for both implemented forecasting methods – linear regression analysis (LRA) and extrapolating a moving average analysis (EMA). Initial data is delivered in Figure 16 as obtained from UNEP/BNEF.

The graph below presents the forecast of future investment flows in the RE market, using **linear regression analysis** (LRA), *(method 5.2.1)*.



	2'04	2'05	2'06	2'07	2'08	2'09	2'10	2'11	2'12	2'13	2'14	2'15	2'16	2'17	2'18	2'19	2'20
Developing c.	9	20	29	46	60	64	75	87	106	98	131	156	153	165	177	189	202
Developed c.	37	53	83	108	123	114	164	191	151	136	142	130	179	189	198	207	217
Total investments	46	73	112	154	183	178	239	278	257	234	273	286	332	354	375	397	418

Figure 16. Linear regression forecast of RE investment flow for the years 2016-2020

LRA demonstrates the growing channel trend of RE in a sense of money invested. Each of the trend lines displays a positive angle, meaning the higher cash inflow is expected in the next five years. By the same token, the trend line of the developing countries is more rapid than the line of the developed ones. If until 2011 the investment share of developed countries was around 70-80% of the total volume, then during the past few years it decreased to approximately 45-55%. As mentioned in Section 6.2, the activity of European countries decreased recently. Emerging economies, like China, Brazil and India, switched their investment politics, hence strengthening renewable power positions to contribute around 70-80% of all investment volume in the developing economies per annum. China is the key energy RE capacity enlarger in the world, allocating 36% (or two-thirds of the volume from developing countries) of total investments in alternative power sector in 2015. Due to these factors, for the first time ever the contribution to RE assets from the developing countries overcame the developed economies financing.

Linear regression statistical equation predicts continuing rise of RE popularity and a gradual growing investment volume annually. The gap between investment trend lines diminishes, stating that only by 2025 the developing economies will outreach the developed ones, notwithstanding the present reality and data records. Contradictions arise because historical data indicates a dominance of developed countries up to the year 2014. But as a forecasting method, LRA also has its advantages. This method is the most effective in times of stable economic conditions and during continuing growth of electricity demand. The growing electricity demand contributes in assessing extra financial resources in this market segment. The more recent data for linear regression analysis is prioritized over earlier data in geometric progression. This is why the developing trend line reaches the developed one due to the well-disposed data of 2015. The principal drawback of this method is inability to make a clear and reliable prediction during times when investment flows are chaotic. That appears during times of economic and financial crises; the restructuring of governmental priorities, national calamities or increased military tension. The world is need driven - linear regression analysis does not involve changing market conditions, seasonality and life cycle of renewable power products. Technological advancements, as well as innovation in the RE sector might have a major impact on the accuracy of future flow projections. Linear regression analysis, as a statistical method, is a first step to fully work out **RQ**3.

The research continues with a second forecasting method – **extrapolating a moving average** (EMA). In this research, this method uses the same initial data as in Figure 16. Results of the EMA analysis *(method 5.2.2)* are presented in Figure 17.

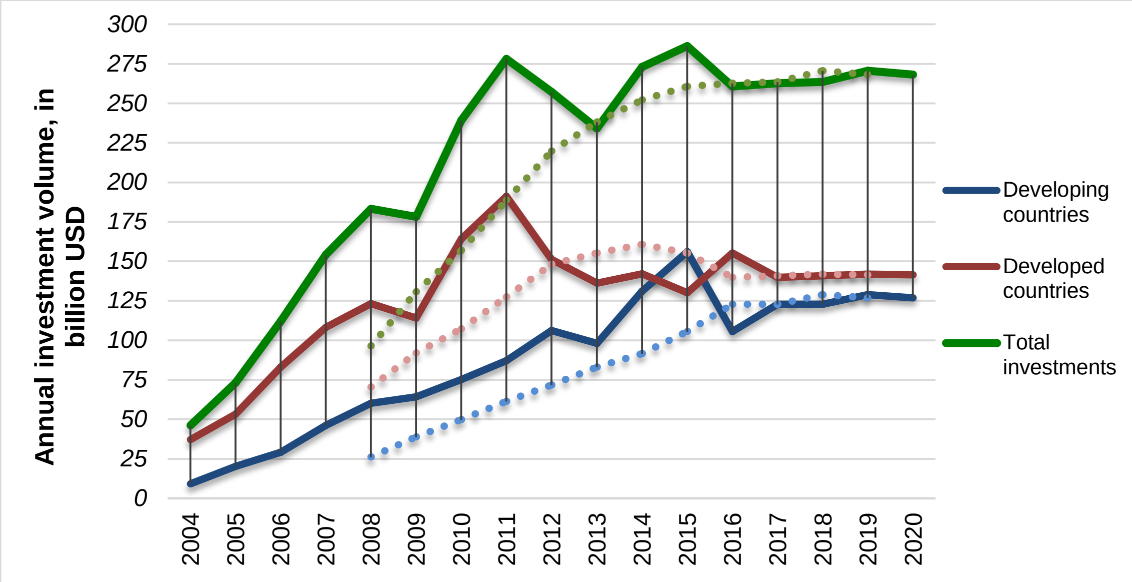


Figure 17. Forecasting future investments flows by extrapolating a moving average

Unlike LRA, forecasting through EMA analysis predicts continuing dominance of developed countries, the investment volume of which reaches 141.4 billion USD by 2020. For developing countries, this number decreases to 126.7 billion USD in five years. Such considerations contributes to assumption that the total volume invested in the renewable power will have a slight decline of investment volume to 268 billion USD in 2020, as based on the historical data between the years 2004 and 2015. The gap between the trend lines will diminish to 5% difference in five years. This forecasting method is less reliable when projecting up-and-coming products as it is in the case of renewable power.

The advantage of this forecast is a simple calculation and visual illustration of changing investment flows in context of the past few years. That is extremely effective in cases, where wide swings of volatility emerge. For investors, high volatility is a signal of a bigger opportunity and a greater risk. Another advantage of this statistical method is the account of external economic-historical factors.

A major drawback of EMA method is that the provided data has equivalent value to the research, which diminishes the believability of investment forecasting. For more accurate trend forecasting, the recent data must be of a much higher value than the older one. Otherwise, the preciseness of the analysis descends in constantly changing market conditions and social acceptance of renewables. Finally, when forecasting, it is vital to mention that EMA analysis will always have a pessimistic scenario, meaning that analysis results can never reach a top historical value. Taking into account current tendencies of rapid growth of volume invested by emerging economies, as well as numerous recent conventions, the chance of even higher investment volume in upcoming years is extremely likely. Same as LRA, EMA analysis corresponds in answering on **RQ**3.

LRA and EMA forecasting methods provide a good basis for marking the worst and best-case scenarios in future investment behaviour so that investors and those willing to initiate their business in RE field can find the best business and investment climate.

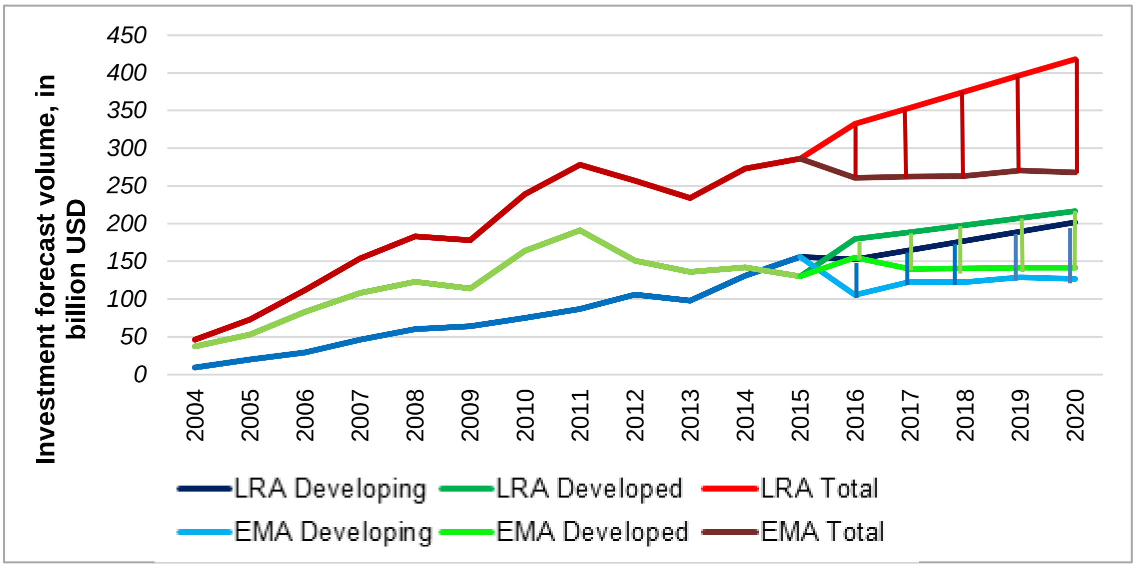


Figure 18. Aggregate differentiation in forecasting between Figure 16 (LRA) & Figure 17 (EMA)

As mentioned before, the growing trend channel of linear regression analysis is more optimistic and shows actual tendencies with stronger relation the recent historical data values together with only minor weight of the older data. Forecasting by EMA, as proved in Figure 18, decreases the top value of 2015. With the help of the LRA and EMA analyses, it is possible to conclude the interval and mean global projected investment volume for the next five years (following the **RQ**1 – **RQ**3) in the amount of:

- 2016: *260.5 – 332.2 billion USD (avg. 296.35 billion USD).*
- 2017: *262.5 – 353.7 billion USD (avg. 308.1 billion USD).*
- 2018: *263.4 – 375.2 billion USD (avg. 319.3 billion USD).*
- 2019: *270.5 – 396.7 billion USD (avg. 333.6 billion USD).*
- 2020: *268.1 – 418.2 billion USD (avg. 343.15 billion USD).*

6.4 Probability of temperature increase

The goal of this method is to foretell the chance of the annual mean global surface temperature increase, following the **RQ**4. To follow through, analysis of the global land-ocean temperature index by NASA "Global Climate Change" was implemented:

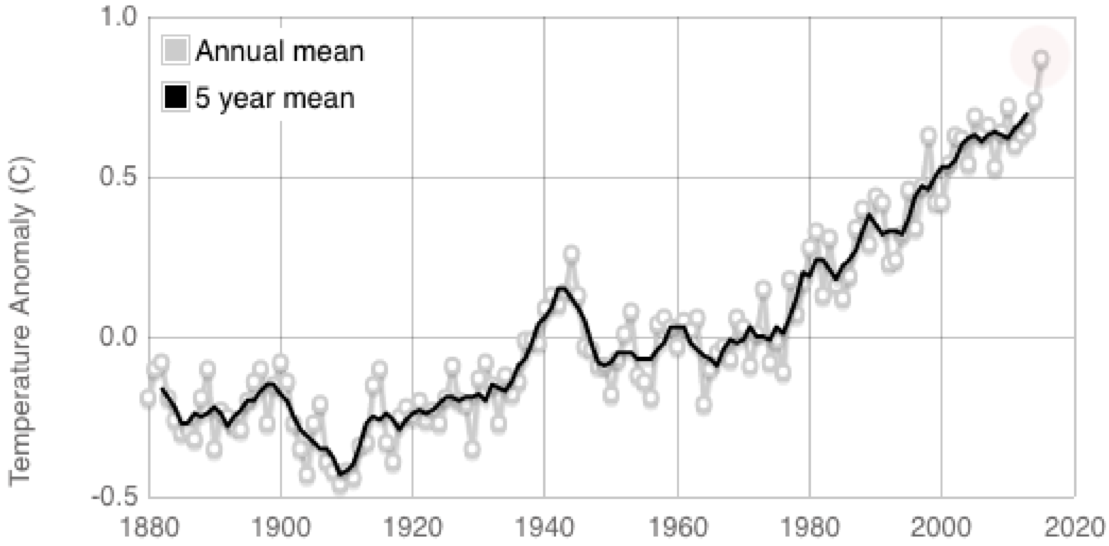
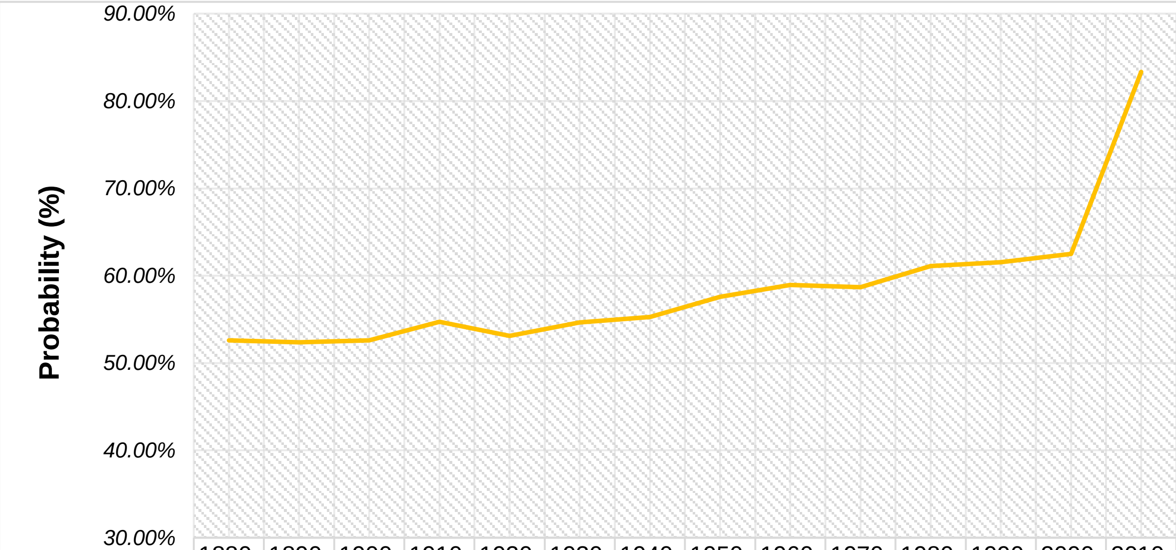


Figure 19. Global Land-Ocean Temperature Index (NASA/GISS, 2016)

Figure 19 depicts industrialisation effect on global warming starting from 1880's. Ubiquitously people tend to seek close interrelation between global warming and consequences of The Second Industrial Revolution. The range between 1880's and 2010's data is close to 1°C (NASA/GISS, 2016), albeit the temperature change happened due to other reasons. Until 1936, the temperature was relatively stable with episodic fluctuations. Later on, based on NASA Goddard Institute for Space Studies, head and shoulders chart pattern appears between the years 1933 and 1951 – the time of The World War II, pre-war events and its aftermath. The temperature anomaly above 0°C (in this case head of the chart) appears during the time period of 1940-1945. The military weapon (including atom bombs, artillery and gunpowder), fire, devastating usage of nature to strategic goals, the need for huge burial spaces, above-limits metallurgical production and wartime oil tanker disasters resulted in devastating effects on human history and nature as such (KM, 2003). The mean land-ocean temperature had raised by 0.5°C during the wartime in comparison to the "Day of Potsdam" on March 21, 1933.

The after-war recession period lasted until 1975, when channel trend line started a rapid increas and continued up to today. As was already mentioned in this work, the initial causes for climate change were the development of world economy and rising human living standards – the higher gross domestic product was, the more energy was needed to produce it. Hence, more greenhouse gases were emitted, as discussed in Section 2.3. The increased amount of GHG in the atmosphere is one the causes of global warming – the assumption is made by correlating Figures 2 and 19. The occurence of dramatic climate change occured, coupled with other uncontrollable presumable causes, like solar variability, Albedo and ocean currents led to temperature increase in the last 40 years (Bast, 2010).

The main focus of this research *(method 5.3.1)* is directed towards a prediction of the mean surface temperature increase in the following year as compared to the preceding year. As a research basis, the data of mean land-ocean temperature of the past 136 years is used (see: Figure 19). The research results are illustrated in Figure 20.



	1880-2015	1890-2015	1900-2015	1910-2015	1920-2015	1930-2015	1940-2015	1950-2015	1960-2015	1970-2015	1980-2015	1990-2015	2000-2015	2010-2015
Pn↑(t°C)	52.59	52.38	52.59	54.72	53.13	54.65	55.26	57.58	58.93	58.70	61.11	61.54	62.50	83.33

Figure 20. Probability of global surface annual t°C increase in 2016

NASA GISS open data starting from 1880's grants a unique opportunity to analyse the rise of global surface temperature since the Second Industrialisation of the 1880's. The chart line of Figure 20 almost symmetrically repeats the actual data trend line, as presented in Figure 19. By completely relying on just statistical information, the author interprets the results of the findings - the more recent data is taken into an account, the more likely is that the global temperature is expected to continue to grow in the following year. It is wrong to state that global warming started at the peak of industrialism. This statement is incorrect because the probability in 1880's-1930's is nearly over 50%, which may be the result of minor fluctuations or circular enhances of solar activity. The rate of 50% is the average probability that keeps the surface in the consistent weather conditions. There is no need to remind of the fact that relative data is analysed here, which starting from 1980's is over 60%. The recent data is more prioritized in this research and is examined in a completely different way, because the ongoing weather conditions are extremely different from the climate of a hundred years back. The rate of 52-56% during the intervals 1880-2015 and 1940-2015 is connected with a higher probability data of temperature rise starting from 1980's. In the past six years, the temperature has increased five times out of six, when comparing the actual year to the preceding one.

Summing up, this statistical method proved that global warming is a contemporary issue, consequences of which were realized after the World Wars and the industrialization time. It is not a surprise that leaders of G8 do their best to prevent ecological collapse by promoting ecological initiatives, such as gas emission quotas, renewable energy enhanced deployment and energy efficiency programs. As a method of current research work, it facilitates in partly answering **RQ**4.

6.5 Consumption-to-Emission comparative analysis

In Section 3.1 of this work, the current situation of world energy consumption was reviewed. Figure 5 depicted the share of world energy consumption in 2015, where the best part of consumed power was generated from FF – 86%. This research attempted to measure the relative increase of energy consumption starting from 2004 *(method 5.3.2)*. Subsequently, comparative analysis between the increase rates of world energy consumption and CO_2 increase was implemented, following **RQ**4.

This research addresses the data, gathered from British Petroleum Annual Statistical Review of World Energy Workbook (British Petroleum, 2016). Analysis results in Figure 21 deliver contrast between the increase rates of different energy sources. Familiarization with calculation procedure is attached in *Appendix (2) 1*, *Table 2–4*.

As Figure 21 illustrates, the consumption of almost every energy source has a positive trend line, i.e. increased in the past dozen years. As a positive signal of world economy development, it correlates with a larger amount of greenhouse gas emitted to the surface. The fall of energy consumption is observed when the crisis hits the ground. The year 2009 is linked with severe world financial crisis, which affected all economic sectors and private finances. An after-effect results in lower energy consumption levels, as represented in Figure 21. The Great Recession was a period of large decline observed in markets, albeit in 2010 energy consumption levels were already ahead of the pre-crisis times.

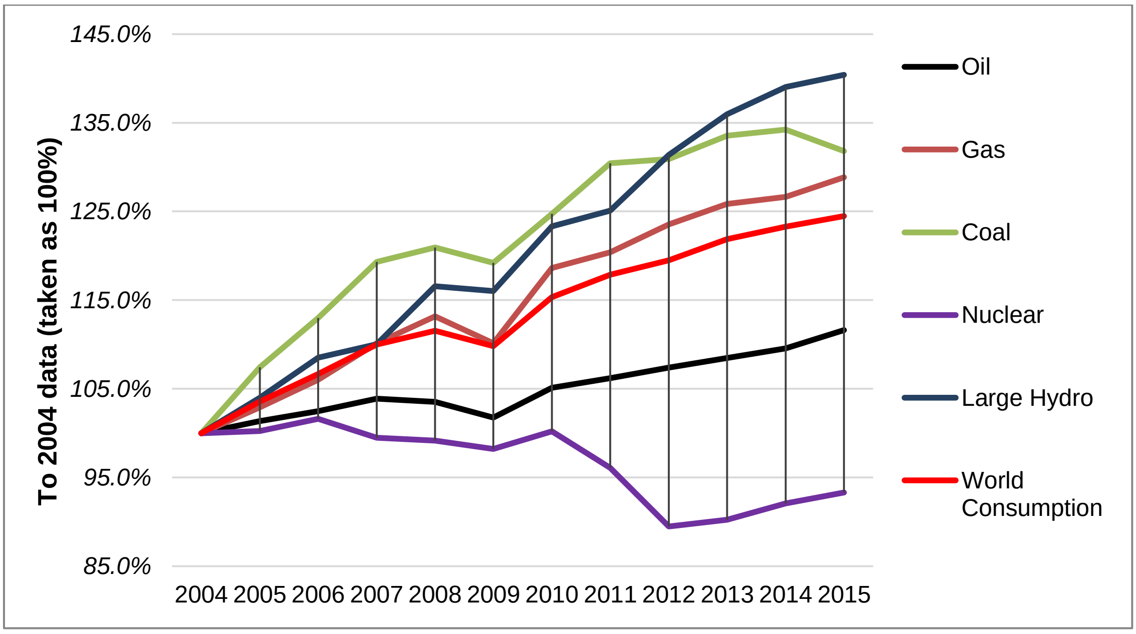


Figure 21. Energy consumption relative increase since 2004

The World Consumption chart in Figure 21 symbolizes power consumption increase rates of the main forms of power to the year 2004. The world consumption trend line is represented as a mean trend line of all exploited power generating technologies. In the following bullet list, the author individually examines every element of Figure 21:

- Oil: In 12 years, oil consumption increased on 11.6%, the lowest margin among presented hydrocarbons. Despite relatively insufficient growth rates, oil still dominates the electricity market, holding 32.94% consumption share in 2015. Price downfall in early 2016 may result in the higher share of power production that year, albeit that cannot last for very long. As Figure 4 stated, proven oil reserves may last for nearly fifty years, i.e. the downturn of oil extraction and consumption levels is extremely likely.
- Gas: Natural gas consumption rates since 2004 increased by 28.85%. The world consumption share on natural gas equals 23.85% in the last reported year. Proven reserves of gas to modern consumption rates will last for just half a century. The recent shale gas revolution in the USA may completely change the pattern of world energetics. Nonetheless, shale gas extraction has decreased in 2015 because of lower prices for traditional types of gases.

- Coal: Coal consumption rates among all fossil fuels are the highest – 31.79% increase to the year 2004. The consumption share in 2015 was 29.21%, which gradually diminishes over time (in the early 20th century – around 60%) (Tverberg, 2012). The largest coal reserves prevail in CIS region, the proven reserves of which can last for roughly 400 years (see: Figure 4). Ecological problems, caused by widespread use of coal, may potentially result in limiting coal mining through the use of various international conventions.
- Nuclear: Nuclear is the only source of power, consumption rates of which diminished since 2004 – a 6.69% decrease. Until 2010, nuclear power had stable ratios – 95-101% to 2004 data. Because of crisis aftermath and Fukushima Daiichi accident on 11 March 2011, the nuclear consumption dropped in 12% by 2012.
- Large Hydro: Large Hydro increased its consumption amount by 40.4% comparing to the year 2004. The world power consumption share in 2015 was 6.79%, which is almost 2.5 higher than the share of renewables. Naturally, large hydropower, just as renewables, is originally connected with electrical power, altogether holding 23.7% (REN21, 2016). The biggest aspect of its large extension is that hydropower is an economically effective power source, providing electricity at lower costs than even fossil fuels.
- Renewables: Not included in Figure 21, consumption rates of RE since 2004 increased by +395.7% - from 325.3 TW to 1612.5 TW, leaving the closest pursuer with +40.4% (see Figure 22). It is false to state that the RE dominates the energy market since its world power share in 2015 was just 2.78%. Nonetheless, Figure 22 is a perfect example of the effect of major investment that was analysed in previous methods, resulting in 2.08% share additions in twelve years.

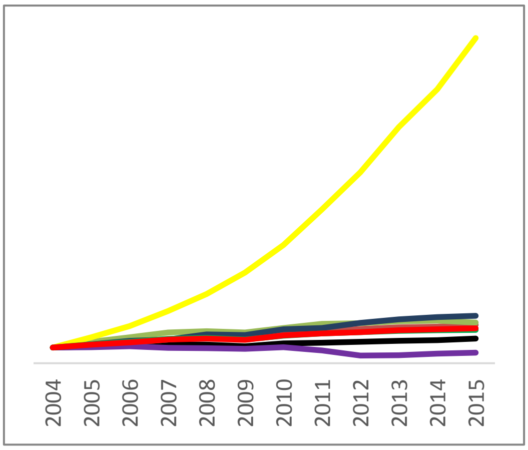


Figure 22. Comparison of RE consumption increase rates to other forms of power

The global power consumption of all energy sources has increased by 24.48% since 2004. This trend surely has a negative affect on climate change by means of larger GHG emissions. To see the effect of energy efficiency programs and larger adoption of

RE installations, consumption-to-emission analysis was carried out for the same time period. The reader can familiarize oneself with its results in Figure 23.

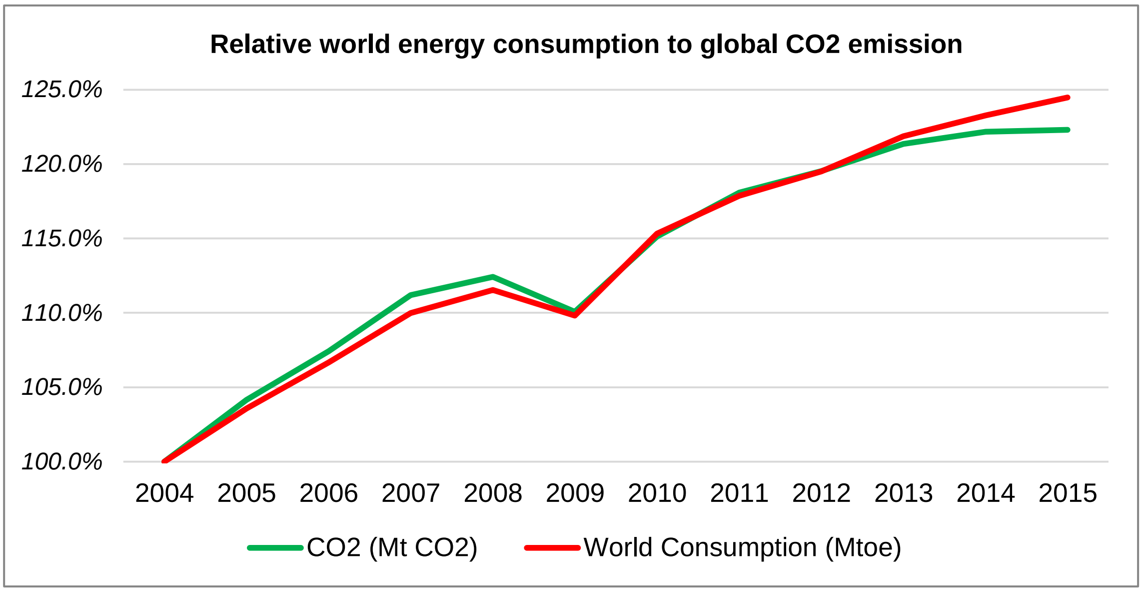


Figure 23. Consumption-to-Emission analysis of world power and global CO_2 increase rates

Prior to tGreat Recession, the CO_2 relative increase was higher than energy production, which is linked with larger extraction of FF and rise of world economy. Only after 2012 the rates of world power consumption started to outreach the increase rates of CO_2 emission. As a positive factor, it means the larger exploitation of energy generation technologies with lower GHG emission, f.e. alternative power technologies – +395.7% and large hydropower – +40.4%. Sustainable energetics, i.e. efficient energy use on corporate and municipal level has a high potential too. International Energy Agency once stated that improved efficiency in daily routine, industries and transportation can reduce the power consumption by one third (International Energy Agengy, 2013, pp. 76-78). Nowadays, it is possible to find more electrocars, fluorescent lamps, efficient healing and cooling systems. Moreover, international conventions put quotas on carbon emissions, favour ecologically free businesses with a large spectrum of policies (described in Section 4.3), and promote a smart grid system building. Social attitude and awareness towards environmental protection and sustainability also changes into a positive flow.

Recent incentives in the power sector forced CO_2 to fall behind relative increase rates of power consumption. In 2015, the widest gap between world power consumption and CO_2 trend lines was detected of past twelve years – 2.17%. Following executed analysis, a full reply on **RQ**4 was given.

7 CONCLUSIONS

7.1 Research findings

The objective of thesis was to measure the overall effect of rising renewable energy investments trends on climate change mitigation. Key findings were interdependent to the **RQ**s, each discussed in a separate paragraph.

Dominance of wind and solar (RQ1)

***RQ**1: What are the investment trends of the 21st century in RE?*

Present RE market conditions enhances the investment dominancy of wind and solar power projects. In 2015, share of annual assets financed through these projects reached 94.68% among all forms of renewable generation technologies. 1.91 trillion USD, or 82.91% of all renewable cash inflow (solar – 45.1%, wind – 37.81%), were invested in wind turbines and solar cells during the past 12 years. A significant increase was connected with the lower initial costs (comparing to biomass, hydropower and geothermal power stations), favourable RE policies and limitless area of deployment. Investment behaviour indicates a switch from biomass and biofuels projects, reasoned by low EROEI ratios and other ways of using burned biomass. Small and medium scale hydropower projects do not allocate as much money as large-scale hydropower projects (see: Figure 10 and 12) due to a comparatively lower profit potential. Geothermal stations are financially feasible in only limited regions due to the nature of geological activity beneath the ground.

Aforementioned reasons, along with the social awareness factor gradually tending to enhance its authority, encouraged a massive switch to solar and wind energetics Solar and wind projects generate only a minor part of electrical power capacity – 4.9% (see Section 3.1).

Growing role of emerging economies (RQ2)

***RQ**2: What global regions played leading roles in global climate financing in the past dozen years?*

Rapid commercialization of renewables became a global tendency. CAGR analysis identified the rising influence on allocating the cash from all the regions. Africa and Middle East are likely to increase its significance due to having the highest demand for electricity, perfect geolocation for placing solar cells and superior CAGR rates – 31.79%. China, the new investment grandee, invested 36%, or 102.9 billion USD, of total cash directed to renewables in 2015. Along with forecasting methods, the greater role of emerging economies (China, Brazil and India) resulted in the first higher annual contribution of developing economies to financing RE facilities. Investments are likely to grow in the next 5 years from every single global region, according to LRA and CAGR analysis. EMA projected a slight drop of volume, albeit this method was considered the least reliable when forecasting up-and-coming products. Both forecasting methods displayed an enhanced role of developing countries in the next 5 years. However, the statistical approach does not specify actual trends, as it relies on dominant position of developed economies until the year 2014. This stood in contradiction with current interest decline by European countries, though calculated CAGR signified an investment rise of 6.35% from the preceding year. The rising forecasted volume is the best indicator of growing concern towards sustainability programs and their accessibility in today's world.

Renewables are not yet competitive to fossils (RQ3)

***RQ**3: What is the scale of RE compared to other power sources and what forms of renewables are likely to increase their significance in the world power market?*

Research identified that to fully replace fossils, renewables must go beyond producing only electrical power. Other power consuming segments, like transportation, industrial production and municipalities (households) remain in the realm of hydrocarbons. In the USA, only 19% of consumed energy is connected with electricity (Arutynov, 2016, pp. 19-21). Surely, transportation and municipalities strives to use more electrical power generated from RE sources, but restructuring the entire energy market system is a very slow and serious process. Especially during the crisis times, when low social and investor interest in renewables is recognized (Section 4.3).

Fossil fuels, especially oil and natural gas, are extremely finite. Modern economy development is interrelated with higher energy consumption, where RE up to today holds a minor role – 2.78% globally. Hydrocarbons own 86% of world consumption share in 2015 and the total amount of produced fossils continues to grow. A stimulus is EROEI and LCOE ratios that state the disadvantages of alternative power in terms of energy efficiency and profitability. Only nuclear and large hydropower succeed in their attempts to compete with fossils, albeit they cannot fully meet sustainable development criteria. Renewable mechanisms need to be powered, implying the certain role of fossils during renewable power production process. The cost effectiveness of fossils is expected to decrease due to resource scarcity. However, according to key findings of **RQ**1, wind and solar power projects are likely to increase its role in the next five years.

Analysis of collected data suggests that, after moving past certain barriers, an entirely new set of challenges arise. An inevitable power generation relying exclusively on renewable forms leads to other catastrophic consequences, such as those presented in Table 1. Nevertheless, innovation and technological development may improve current challenges of RE and increase the scale of renewables in terms of other power demanding fields.

Higher energy consumption negative effect on global warming (RQ4)

RQ*4: What is the impact of rising power consumption levels on the climate change?*

Another key finding addresses the dramatic change of the climate occurring in the 20th century. Section 6.4 and 6.5 connects climate change worsening with enhanced military activities, increasing population and continual development of the world economy. Aforementioned factors are tied with a higher power demand, as the author examines in this work. Potential theories of increased solar activity and volcanic soot negative effects were recognized too, although were not statistically measured in this thesis. Nonetheless, this research various externalities of hydrocarbons and their effects on the planet continue to challenge sustainable development.

Consumption-to-emission analysis indicated a rising role of enhanced deployment of renewables and large hydropower stations, energy efficiency tools and recent sustainable development programs. Because of these activities, world consumption increase rates started to overreach the increase rates of CO_2 from 2012. The interpretation of this finding suggests that, by producing more power, humanity began to emit less CO_2, even though the total GHG emission still increased.

Ambiguous statistics and new possibilities (RQ1 – RQ4)

Starting from 2004, finances directed to non-exhaustible power sources reached 2.2 trillion USD. During this time, the share of Earth powered by renewables increased from 0.7% to 2.78%. Share additions equalling 2.08% in twelve years is a low advancement, considering the expected last period of hydrocarbons reserves. The recent Paris Climate Conference creates a new platform to limit GHG emission, which indirectly promotes the enhanced deployment of alternative energy installations.

Renewables are still relatively new to the Earth and their usage increased five times (+395.7%) in the past twelve years. In the past five years (2011-2015) renewables allocated 1.33 trillion USD, resulting in 1.25% RE share additions in total world power consumption. The author predicts more progress in the next five years, based on executed forecasts. Although there may occur booming innovations in alternatives and investing grandee in the RE market, but their occurrence cannot be statistically measured. In Section 7.2, the author wishes to express suggestions for his future research and highlights the challenges facing during the writing and the information gathering process.

7.2 Suggestions for future research

The author is satisfied with conducted research and its interpretation, although time and thesis size restrict the research content. The topic is vast and the only certain indicators are examined in this work. The data is renewed on an annual basis, hence requiring continual investigation in this field. Some suggestions for author's future research, which he believes may occur during his Master Degree studies, are listed below:

- For the more precise forecast, additional methods like ARIMA modelling and forecasting using artificial intelligence can be applied.
- The discussion of exact energy efficiency programs, started in Section 6.5 of this thesis, shall be continued and statistically approved.
- To which extent RE can possibly supply other economy sectors with energy – in transportation, municipality and industrial production levels.
- Specification and a research of other global climate change factors: mean sea level rise, deforestation, deglaciation.

The research shares similarities with UNEP and Bloomberg New Energy Finance, as well as other numerous respected agencies, like Energy Information Administration, Environmental Protection Agency and British Petroleum. Following their findings, author attempted to find relatively new patterns by executing statistical analysis, completely relying on their data. Statistical approach in finding interdependence between rising renewable investment trends, mitigation of greenhouse gas emission and the shape of world energy consumption is a distinctive approach of the author.

"To truly transform our economy, protect our security, and save our planet from the ravages of climate change, we need to ultimately make clean, renewable energy the profitable kind of energy". – Barack Obama (Address to Joint Session of the United States Congress at 24.02.2009).

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APPENDIX (1) – METHODS OF THE RESEARCH

Compound Annual Growth Rate (CAGR)

The steps for calculating compound annual growth rate (CAGR):

1. *Growth rate*: $\boldsymbol{GR_n/GR_{n-1}}$
2. *Compound annual growth rate:* $\sqrt[n-1]{GR2\ /\ 1 * GR3\ /\ 2 * \ldots * GRn\ /\ n-1}$
3. *Average growth rate:* ***Average annual growth rate * 100%***
4. *Relative growth rate:* ***AGR – 1***

n *– Ordinal year's number of investigated object*

Equation 1. Compound Annual Growth Rate

Linear regression analysis

In investment volume forecasting, the following equations are used:

1. The construction of a linear function depending on the forecasted value to the time

$\boldsymbol{y = a_0 + a_1 x}$, *Equation 2. Linear function formula*

This function must satisfy the conditions to minimize the sum of squared deviations of actual values $\boldsymbol{y_i}$. This function corresponds to the regression line from its actual values $\boldsymbol{y_{i\ avg}}$, which is obtained from retrospective data within this period (Equation 3). Parameters a_1 and a_0, have to satisfy this condition and be determined by the system of two linear equations with two unknowns (Kunin & Rumyantceva, 2014).

$$\sum_{i=1}^{n}(y_i - y_{i\ avg.})^2 \rightarrow \min$$

Equation 3. Conditions to minimize the sum of squared deviations

2. *Equation 4. Linear regression system*

$$\sum_{i=1}^{n} y_i = na_0 + a_1 * \sum_{i=1}^{n} x_i$$

$$\sum_{i=1}^{n} x_i y_i = a_0 * \sum_{i=1}^{n} x_i + a_i * \sum_{i=1}^{n} x_i^2$$

Where, $\boldsymbol{a_0}$ *and* $\boldsymbol{a_1}$ *– values to minimize the total square deviation of the actual values* y_i

$\boldsymbol{x_i}$ *– nomenclated number of the period i.*

$\boldsymbol{y_i}$ *– the value of the period i*

n *– Number of analysed periods (years)*

Extrapolating a moving average analysis

Steps to complete EMA analysis are the following:

1. Set a range, which is measured in a specific number (***n***) of periods. In this research, ***n=4*** (i.e. 4 years).
2. Mean value of the data is calculated according to previously set ***n*** of periods.
3. This range is then shifted by one period, thus the newest periodic data is added, excluding the oldest one. New average value forms new anti-aliasing.
4. That procedure is repeated up until the calculation of the forecasted period, where mean value forms expected investment volume for the future period. This value, as an actual data, is used to analyse global investment volume for the following years (Kunin & Rumyantceva, 2014).

Equation 5. Steps for extrapolating a moving average

The Probability Theory

Classic probability equation, used in this research:

$P_n(A) = \frac{m}{n}$, *where*

Equation 6. Classical probability formula

m *– Number of favourable outcomes of an event* ***A***

n *– Number of all outcomes of an event* ***A***

A – *t°C increase comparing to the previous year* ($t°C_{year} > t°C_{year-1}$)

Comparative analysis

The year 2004 is taken as n_{const} in order to measure the increase rates in the subsequent years between different variables. Formula used to perform this analysis:

$(\frac{n}{n_{const.}} *100\%) - 1$

Equation 7: Relative increase comparative formula

n – Value of the analysed period (year)

n_{const} – Value compared to values ***n***

All energy generation forms were conversed into the same value – Million tonnes oil equivalent (Mtoe). The approximate conversion rates of Mtoe to TW are ~ 1:4.4.

APPENDIX (2) – CALCULATIONS

The author does not include all statistical projections in the appendix part of this work. This appendix demonstrates an example of the research method described in Section 5.3.2 and its later data analysis, discussed in Section 6.5. If the reader wishes to get introduced to other conducted methods (5.1.1; 5.1.2; 5.2.1; 5.2.2 and 5.3.1) in the Excel Sheet, you can freely contact him through his e-mail: *rihardsnovikovs@inbox.lv*

Table 2. World energy consumption initial data, gathered from BP (British Petroleum, 2016)

World energy consumption 2004-2005 initial data from British Petroleum							
	Oil (Mtoe)	Gas (Mto	Coal (Mtoe)	Nuclear (TW	Hydro (TW)	RE (TW)	CO2 (Mt CO2)
2004	3881.1	2433.3	2913.7	2762	2810.8	325.3	27397.1
2005	3933.9	2504.5	3130.6	2768.5	2923	367.5	28533
2006	3977.2	2579.4	3292.2	2806.3	3050.2	415	29429.2
2007	4032.3	2679.8	3476	2747.8	3092.3	476.5	30465.2
2008	4018.1	2753.7	3523.9	2739.1	3276.5	547.7	30799.7
2009	3948.7	2680.2	3473.6	2713.1	3261	637.4	30158
2010	4079.9	2886.7	3634.3	2767.7	3465.9	751	31544.1
2011	4121.6	2929.3	3800	2653.4	3515.8	899.9	32353.3
2012	4168.6	3005.8	3814.4	2471.7	3692.7	1053.8	32742.8
2013	4209.9	3062.5	3890.7	2492.7	3822	1242.4	33248.1
2014	4251.6	3081.5	3911.2	2543.2	3908	1399.2	33472
2015	4331.3	3135.2	3839.9	2577.1	3946.3	1612.5	33508.4

Table 3. Conversion of TW into the same unique derived unit – Mtoe

World energy consumption conversed in million tonnes oil equivalent (Mtoe)								
	Oil (Mtoe)	Gas (Mtoe)	Coal (Mtoe)	Nuclear (Mtoe)	Hydro (Mtoe)	RE (Mtoe)	CO2 (Mt CO2)	World C. (Mtoe)
2004	3881.1	2433.3	2913.7	627.7	638.8	73.9	27397.1	10568.58
2005	3933.9	2504.5	3130.6	629.2	664.3	83.5	28533	10946.05
2006	3977.2	2579.4	3292.2	637.8	693.2	94.3	29429.2	11274.14
2007	4032.3	2679.8	3476	624.5	702.8	108.3	30465.2	11623.69
2008	4018.1	2753.7	3523.9	622.5	744.7	124.5	30799.7	11787.36
2009	3948.7	2680.2	3473.6	616.6	741.1	144.9	30158	11605.11
2010	4079.9	2886.7	3634.3	629.0	787.7	170.7	31544.1	12188.31
2011	4121.6	2929.3	3800	603.0	799.0	204.5	32353.3	12457.51
2012	4168.6	3005.8	3814.4	561.8	839.3	239.5	32742.8	12629.30
2013	4209.9	3062.5	3890.7	566.5	868.6	282.4	33248.1	12880.62
2014	4251.6	3081.5	3911.2	578.0	888.2	318.0	33472	13028.48
2015	4331.3	3135.2	3839.9	585.7	896.9	366.5	33508.4	13155.47

Table 4. Comparative method results of consumption-to-emission analysis relative increase

Consumption-2-Emission analysis: Relative increase since 2004								
	Oil (Mtoe)	Gas (Mtoe)	Coal (Mtoe)	Nuclear (Mtoe)	Hydro (Mtoe)	RE (Mtoe)	CO2 (Mt CO2)	World C. (Mtoe)
2004	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2005	101.4%	102.9%	107.4%	100.2%	104.0%	113.0%	104.1%	103.6%
2006	102.5%	106.0%	113.0%	101.6%	108.5%	127.6%	107.4%	106.7%
2007	103.9%	110.1%	119.3%	99.5%	110.0%	146.5%	111.2%	110.0%
2008	103.5%	113.2%	120.9%	99.2%	116.6%	168.4%	112.4%	111.5%
2009	101.7%	110.1%	119.2%	98.2%	116.0%	195.9%	110.1%	109.8%
2010	105.1%	118.6%	124.7%	100.2%	123.3%	230.9%	115.1%	115.3%
2011	106.2%	120.4%	130.4%	96.1%	125.1%	276.6%	118.1%	117.9%
2012	107.4%	123.5%	130.9%	89.5%	131.4%	323.9%	119.5%	119.5%
2013	108.5%	125.9%	133.5%	90.2%	136.0%	381.9%	121.4%	121.9%
2014	109.5%	126.6%	134.2%	92.1%	139.0%	430.1%	122.2%	123.3%
2015	111.6%	128.8%	131.8%	93.3%	140.4%	495.7%	122.3%	124.5%