MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ECOLOGY

APPROVED TO DEFENCE
Head of the Graduate Department
_____ V.F. Frolov
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BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 «ECOLOGY»,
TRAINING PROFESSIONAL PROGRAM
"ECOLOGY AND ENVIRONMENTAL PROTECTION"

Theme: «Analysis of Ukraine's prospects for fossil fuels phase out»

Done by: student of the FESET – EK-402 group, Maryna S. Ponomarenko
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KYIV 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ В.Ф. Фролов
«_____» _____ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»
ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Оцінка перспектив України щодо відмови від викопних палив»

Виконавець: студентка групи ЕК-402**,** Пономаренко Марина Сергіївна
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КИЇВ 2020

NATIONAL AVIATION UNIVERSITY
Faculty of Environmental Safety, Engineering and Technologies
Department of Ecology
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(code, name)

APPROVED
Head of the Department
_____ Frolov V.F.
«____» _____ 2020

QUALIFICATION PAPER ASSIGNMENT
Maryna S. Ponomarenko

1. Theme: « Analysis of Ukraine's prospects for fossil fuels phase out » approved by the Rector on April 27, 2020, № 527/ст.

2. Duration of work: from 25.05.2020 to 21.06.2020.

3. Input work (project): Statistical data from various information sources including literature: books & scientific articles as well as Ukrainian and foreign specialized sites.

4. Content of explanatory note : Analyze the state of the energy sector in Ukraine and the world, analyze current deposits and the future of fossil fuels, assess the potential of Ukraine and the world to meet all their needs through their own fossil fuels, analyze possible sources of alternative energy and legislation, assess the potential of Ukraine and the world to meet their needs at the expense of renewable energy, to make the comparative characteristic of climatic and economic possibilities of development of alternative energy sources in Ukraine, to draw conclusions about current introduction and possibilities of development of this direction in our country.

5. The list of mandatory graphic (illustrated materials): tables, figures, diagrams.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	27.04.2020	
2	Preparing the main part (Chapter I)	29.04.2020	
3	Preparing the main part (Chapter II)	13.05.2020	
4	Preparing the main part (Chapter III)	21.05.2020	
5	Formulating conclusions and recommendations of the thesis	27.05.2020	
6	Making an explanatory note to the previous presentation of the department, consultation with the norms controller	05.06.2020	
7	Presentation of the work at the department	06.06.2020	
8	Taking into account the comments and recommendations and training to protect	12.06.2020	
9	Thesis defense at the department	17.06.2020	

7. Date of task issue: «27» April 2020

Diploma (project) advisor: _____ Margaryta M. Radomska
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ _____
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет екологічної безпеки, інженерії та технологій
Кафедра екології
Спеціальність освітньо-професійна програма: спеціальність 101 «Екологія»,
ОПП: «Екологія та охорона навколишнього середовища»

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____Фролов В.Ф.
«____» _____ 20__ р.

ЗАВДАННЯ
на виконання дипломної роботи
Пономаренко Марини Сергіївни

1. Тема роботи ««Оцінка Перспектив України щодо відмови від викопного палива » затверджена наказом ректора від «27» квітня 2020 р. №527/ст.

2. Термін виконання роботи: з 25.05.2020 р. по 21.06.2020 р.

3. Вихідні дані роботи: Статистичні дані з різних інформаційних джерел включаючи літературу, в тому числі книги та наукові статті, а також Українські та іноземні сайти.
4. Зміст пояснювальної записки: Проаналізувати стан енергетичного комплексу в Україні та світі, проаналізувати поточні поклади та майбутнє горючих копалин, оцінити потенціал України та світу в задоволенні всіх своїх потреб за рахунок власних корисних копалин, проаналізувати можливі джерела альтернативної енергетики та законодавство, оцінити потенціал України та світу в задоволенні своїх потреб за рахунок відновлюваної енергетики, скласти порівняльну характеристику кліматичних та економічних можливостей розвитку альтернативних джерел енергії в Україні, зробити висновки про поточне запровадження та можливості розвитку цього напрямку в нашій країні.
5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.
6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	27.04.2020	
2	Підготовка основної частини (Розділ І)	29.04.2020	
3	Підготовка основної частини (Розділ ІІ)	13.05.2020	
4	Підготовка основної частини (Розділ ІІІ)	21.05.2020	
5	Формулювання висновків та рекомендацій дипломної роботи	27.05.2020	
6	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	05.06.2020	
7	Представлення роботи на кафедрі	06.06.2020	
8	Урахування зауважень, рекомендацій та підготовка до захисту	12.06.2020	
9	Захист роботи на кафедрі	17.06.2020	

7. Дата видачі завдання: «27» Квітня 2020 р.

Керівник дипломної роботи : _____ Радомська М.М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ _____
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Analysis of Ukraine's prospects for fossil fuels phase out»: 67 pages, 25 figures, 5 tables, 57 references.

Object of research – fossil fuels use for energy generation.

Subject of research – transition from fossil fuels to alternative energy sources.

Aim of work – the aim of the work is the assessment of the structure of modern energy supply and future prospects & opportunities for Ukraine to become energy independent in the gradual abandonment of fossil fuels, and its replacement by more ecologically friendly and renewable sources.

Methods of research: analysis, data comparison, statistical data processing.

FOSSIL FUELS ABANDONMENT, RENEWABLE ENERGY SOURCES, MODERN ENERGY SUPPLY, GLOBAL WARMING, ENERGY INDEPENDENCE, GREEN TARIFF, STRATEGY.

CONTENT

INTRODUCTION

Relevance of the work. The largest energy source used in the world today is fossil fuels. Its overconsumption leads to severe environmental problems including air pollution. The importance of researching the production of renewable energy is evident as it plays a crucial role in reducing greenhouse emissions, reducing the negative effect on the atmosphere, improving energy protection and decreasing energy import dependence. Energy independence is very important for our country and can provide great opportunities in the economic and ecological perspectives.

Aim and tasks of graduate work. The aim of the work is to analyze the existing and potential solutions to substitute fossil fuels with alternative sources.

Tasks of work:

1) To analyze the structure of modern energy supply
2) To evaluate the perspectives of Ukraine in the transition to alternative energy.
3) To choose a strategy for the development of alternative energy sources in Ukraine based on different outlooks.

Object of research – fossil fuels use for energy generation.

Subject of research – transition from fossil fuels to alternative energy sources.

Methods of research. Comparative analysis, data comparison, statistical data processing.

The practical value of the results obtained. The recommendations on the development of alternative energy sources and the possibility of meeting the needs of Ukraine at the expense of these sources were proposed.

Personal contribution of the graduate. Analysis of structure of modern energy supply, experience of Ukraine and other countries in the field of alternative energy, opportunities, prospects and already implemented projects. An assessment of our country's ability to meet its energy need through alternatives carried out.

Approbation of results. Theoretical provisions of the study were presented at international and national scientific and practical conferences: “Техногенна-екологічна безпека України: стан та перспективи розвитку (Irpen, 2019), XX Міжнар.наук.-практ. Конф. «Політ. Сучасні проблеми науки» (Kyiv, 2020).

Publications. The main provisions and results of the study are presented in 2 thesis in conference proceeding.

CHAPTER 1

STRUCTURE OF MODERN ENERGY SUPPLY IN THE WORLD AND UKRAINE

1.1 Main energy resources of the modern economy

Commercial energy, or energy sold on the marketplace, is what we are using to complement the energy of the sun. Most business energy is currently derived from the extraction and burning of non-renewable power resources from the Earth's crust, mainly carbon-containing fossil fuels – oil, natural gas, and coal.

Approximately 90% of the world's business energy consumption comes from non-renewable energy resources, 85% from fossil fuels (oil, natural gas and coal) and 5% from nuclear power (Fig. 1.1). Compared to most other options, non-renewable fossil fuels are commonly used because they are abundant, transportable, and inexpensive. Every year since 1982, world power consumption has risen.

Ukraine is one of Europe's largest nuclear power manufacturers: it has 15 nuclear power plants with a capability of over 13 gigawatts, which means that the nation derives around 60% of its electricity from nuclear power [26].

Domestically extracted oil volumes are falling each year, and Ukraine is highly dependent on imported petroleum. Most oil refineries in the country are not in operation.

Ukraine acquired a strong energy industry following the collapse of the Soviet Union. However, this industry is now in a critical state because of inefficient policy. The decline of energy assets and absence of investment, low energy efficiency and acceptability of the environment and heavy reliance on overseas supplies are among the primary issues. Ukraine is one of the world's top 20 least energy-efficient nations. Ukraine spends more energy than Poland three times. To stimulate the operation and development of renewable energy sources in Ukraine, a "green" tariff, or special feed-in tariff, was introduced in 2009. The feed-in tariff for green projects in Ukraine is one of the highest in the world, which makes investment into this sector very attractive. Now the share of

renewable energy sources, as shown in the Figure 1.1, in Ukraine is approximately 5% of total.

In terms of coal reserves, Ukraine ranks 7th in the globe, 12th in terms of uranium and 29th in terms of natural gas. The lack of investment in exploration, processing and energy effectiveness and complex bureaucratic procedures hinder the growth of the energy industry in Ukraine.

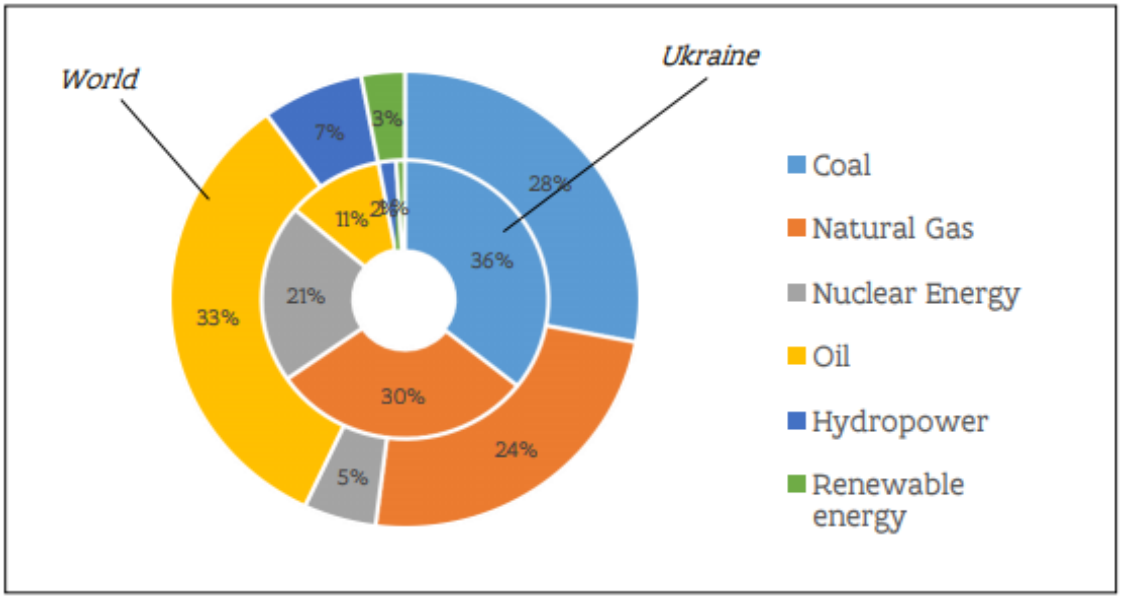


Fig. 1.1. Use by source of commercial energy for the globe and Ukraine [26]

Electricity generation is well known to be the main factor for progress in sector, agriculture, technology and living standards. In the early twentieth century, European and North American industrialized nations consumed about 98 percent of the world's commercial electricity. Growth in the demand for electricity has outperformed growth in the final demand for energy for many years. Increased end-use electrification– such as transportation, space heating, big equipment, and so on – is a main contributor to increasing demand for energy. Electricity consumption in Ukraine is 3,418.59 kWh per capita (2014) as shown in the Fig. 1.2, which is an average compared to other countries [30].

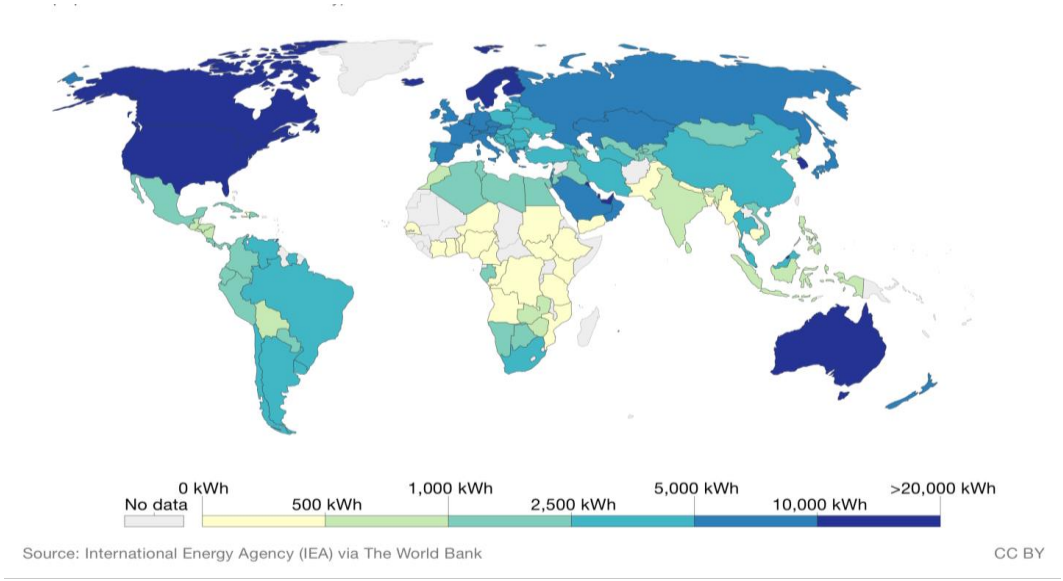


Fig. 1.2. World's electricity consumption (2014) kWh per capita [30]

Modern economic development is mainly dependent and controlled by energy supply. The use of non-renewable and renewable energy sources, pollution and global warming require wise financial choices in terms of energy generation options. The development of unconventional resources and technology improvements are gradually changing the structure of energy consumption (Fig. 1.3).

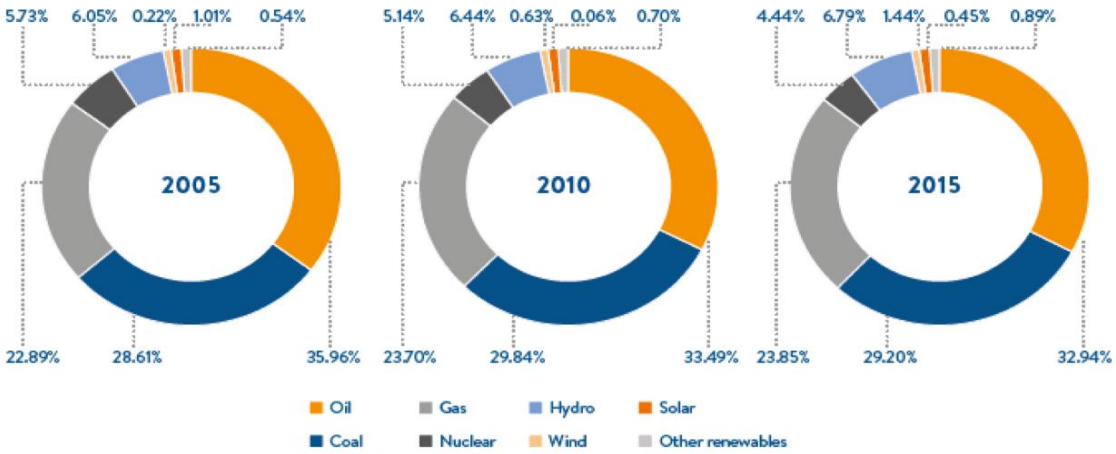


Fig. 1.3. Comparative primary energy consumption dynamics [29]

Economic activity, population, and technology are the three most fundamental drivers of power demand. Long-term financial growth trends for a specific economy rely on fundamental trends in demographics and productivity, reflecting population

development, employment participation rate, productivity development, domestic savings rate and capital accumulation.

1.2 Characteristics of existing fossil fuel reserves

All over the globe, fossil fuels are of enormous importance. Petroleum, natural gas, and coal are the primary energy sources driving contemporary technology, affecting hundreds of millions of people's life.

Overall, more than eighty percent of the world's energy demand comes from fossil fuels, with the main constituents being oil (33%), coal (28%), and natural gas (21%). Fig. 1.4 shows world's total energy production and supply of fossil fuels and energy from alternative sources (hydro, solar, etc.).

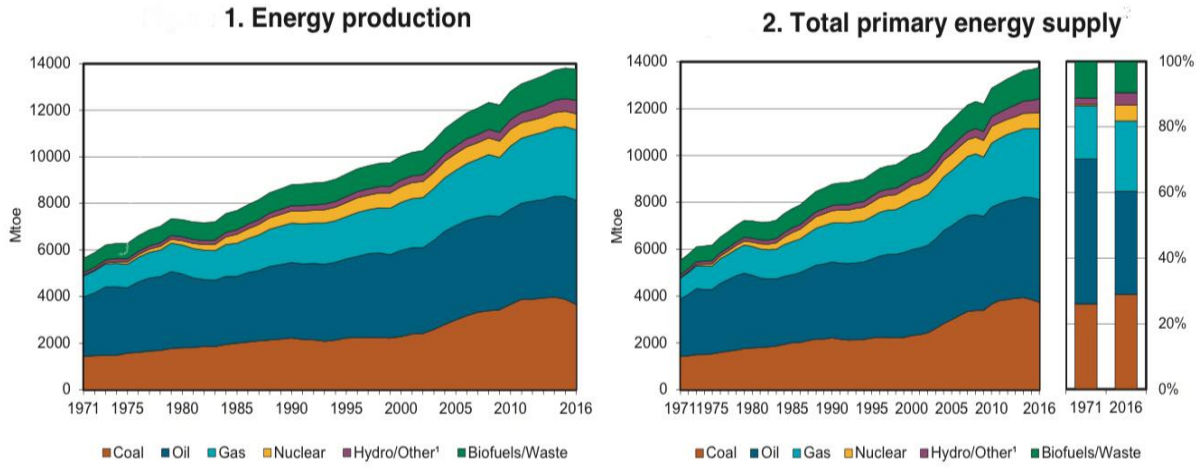


Fig. 1.4. World’s energy production (left) and energy supply (right) (excluding electricity trade) [5]

Petroleum (crude oil) is a black, gooey fluid composed of hundreds of distinct fuel hydrocarbons along with tiny quantities of sulfur, oxygen, and nitrogen impurities. Oil and natural gas deposits are often trapped under a dome deep inside the Earth's crust on soil or under the seabed. In subterranean rock formations, the crude oil is spread in pores and cracks, somewhat like water saturating a sponge. Some crude oil distillation products, called petrochemicals, are used in cleaning liquids, pesticides, plastics, synthetic fibers, paints, medications, and many other products as raw materials.

Developers drill a well vertically or horizontally into the deposit below the bottom of the floor or ocean to obtain the oil. Pressure inside the deposit forces the oil to the surface or oil is drawn from the rock pores by gravity and flows into the well's bottom where it is pumped to the surface.

The oil industry is the biggest enterprise in the world, and control of oil reserves is the single biggest source of worldwide financial and political power. Petroleum is not uniformly spread worldwide. Over half of the world's proven oil reserves are situated in the Middle East (including Iran but not North Africa), meaning the Middle East has more oil than the remainder of the world combined. Canada and the U.S., Latin America, Africa, and the region occupied by the former Soviet Union follow the Middle East. Each of these areas includes less than 15% of the established reserves of the world.

Natural gas is a colorless, extremely flammable hydrocarbon gaseous composed mainly of methane and ethane. It is a form of petroleum frequently found in combination with crude oil. Russia posses the world's biggest natural gas reserves (about 47 trillion cubic meters) and is the biggest producer of natural gas in the world (between 56 and 70 billion cubic meters per year). Groningen is Europe's biggest natural gas field, with initial reserves of approximately 2.27 trillion m^3, the United States has demonstrated 6.6 trillion m^3 of natural gas reserves. The established reserves of Mexico's natural gas are about 370 billion cubic meters [13].

Coal is a material, generally brown or black, rich in carbon, most commonly found in stratified sedimentary deposits. It is one of the most significant fossil fuels. Coal is formed from the remains of land plants buried 300-400 million years ago and exposed to intense heat and pressure over millions of years.

As a fossil fuel burned for heat, coal supplies about a quarter of the world's primary energy and two-fifths of its electricity. Coal is burned in energy plants to produce about 42% of the world's energy, 49% of the energy used in the U.S., and 70% of that is in China [13].

In 2017 38% of the world's electricity came from coal, the same percentage as 30 years previously. In 2018 global installed capacity was 2TW (of which 1TW is in China)

which was 30% of total electricity generation capacity. The most dependent major country is South Africa, with over 80% of its electricity generated by coal [54].

The largest consumer and importer of coal is China. China mines almost half the world's coal, followed by India with about a tenth. Australia accounts for about a third of world coal exports followed by Indonesia and Russia. The US maintains 28% of the world's established coal reserves, followed by Russia (with 18%), China (14%), Australia (9%), and India (7%).

Peat is the organic surface layer of a soil composed of partly decomposed organic material, mostly obtained from plants, which has accumulated under water logging, oxygen deficiency, acidity and nutrient deficiency conditions. Over time, peat formation is often the first step in the geological formation of other fossil fuels like coal, especially low-grade coal like lignite.

By volume, there are about 4 trillion cubic metres (5.2 trillion cubic yards) of peat in the world, covering a total of around 2% of the global land area (about 3 million square kilometres or 1.2 million square miles), containing about 8 billion terajoules of energy. Depending on the agency, peat is not generally regarded as a renewable source of energy, due to its extraction rate in industrialized countries far exceeding its slow regrowth rate of 1 mm per year, and as it is also reported that peat regrowth takes place only in 30-40% of peatlands [28].

Peat is harvested as an important source of fuel in certain parts of the world. Peat has traditionally been used for cooking and national heating in many nations, including Ireland and Scotland, and peat is stacked to dry in rural regions. Peat provides around 6.2% of Finland's annual energy production, second only to Ireland.

Use of peat for energy production was prominent in the Soviet Union, especially in 1965. In 1929, over 40% of the Soviet Union's electric energy came from peat, which dropped to 1% by 1980. Currently, Russia is responsible for 17% of the world's peat production and 20% of that peat (1.5 million tons) is used for energy purposes [55].

Oil shale is an organic-rich fine-grained sedimentary rock containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons can be

produced, called shale oil. Shale oil is a substitute for conventional crude oil; however, extracting shale oil from oil shale is more costly than the production of conventional crude oil both financially and in terms of its environmental impact. Deposits of oil shale occur around the world, including major deposits in the United States. Estonia and China have well-established oil shale industries, and Brazil, Germany, and Russia also utilize oil shale.

1.3 Perspectives for ensuring the needs of fossil resources

All the mentioned energy resources are non-renewable and will eventually come to the end. But if one asks how much of the fossil fuels are still in reserve, the response to this issue is "Nobody understands". The agricultural industry would not exist without the energy industry; the world would not be able to sustain a population of 7 billion or 3.6 billion and maybe not even 1 billion. Hungering our power machines would be starving ourselves.

According to the London, England-based World Energy Council, there are still over 800 billion tones (725 billion metric tons) of coal, 1.2 trillion barrels of crude oil, and 235 trillion cubic yards (180 trillion cubic meters) of natural gas under the surface of the earth [29]. Clearly, due to the finite quantity of remaining reserves, the fossil fuel era is bound to end in a matter of at most a century or two. Global consumption of fossil fuel is rising and finding fresh reserves is becoming more difficult. Those discovered are substantially lower than those found in the past.

Thus, the U.S. in its 2000 global oil supply evaluation Geological Survey estimated that approximately 3 trillion barrels of recoverable oil originally existed on Earth and approximately 710 billion barrels of this amount were consumed by 1995. Globally, we are presently consuming more than 11 billion tons of oil each year from fossil fuels. Crude oil reserves are disappearing at a rate of over 4 billion tons per year – so if we continue as we do, our known oil reserves could run out in just over 53 years [22].

The worldwide long-term perspective for standard supplies of natural gas is better than for crude oil. At current consumption rates, known reserves of conventional natural gas should last the world 62–125 years and the United States 82–118 years [22].

Coal is the richest fossil fuel in the world. Global carbon supplies identified and unidentified could last 214-1125 years, depending on how quickly they are used [22].

Geologist M. King Hubbert in the 1950s anticipated the world would experience a fossil fuel scarcity that would harm the economy of the world. This concept stayed as the Peak Oil theory in the collective consciousness, according to which oil production, as a finite resource, will peak at some stage and eventually decrease and deplete. Overall, we see a more than 1300-fold increase in worldwide fossil energy usage (Fig. 1.5). As shown, until the 1860s, when crude oil consumption started, coal was the first and only fossil source. Production of natural gas started a few centuries ago, in the 1880-90s.

According to Production/Respiration Ratio oil will run out at current production rates in 53 years, natural gas in 54 years, and coal in 110. But, we must bear in mind that all these estimates are based on Production/Respiration ratios and therefore consider only established reserves, unlikely or feasible resource reserves. For example, in 1980, only 32 years of oil production from existing reserves were suggested by the R / P ratio. Some coal, oil, and gas volumes are not currently accessible due to deep localization underground, but the improvement of technologies may have a positive impact on the available reserves volume.

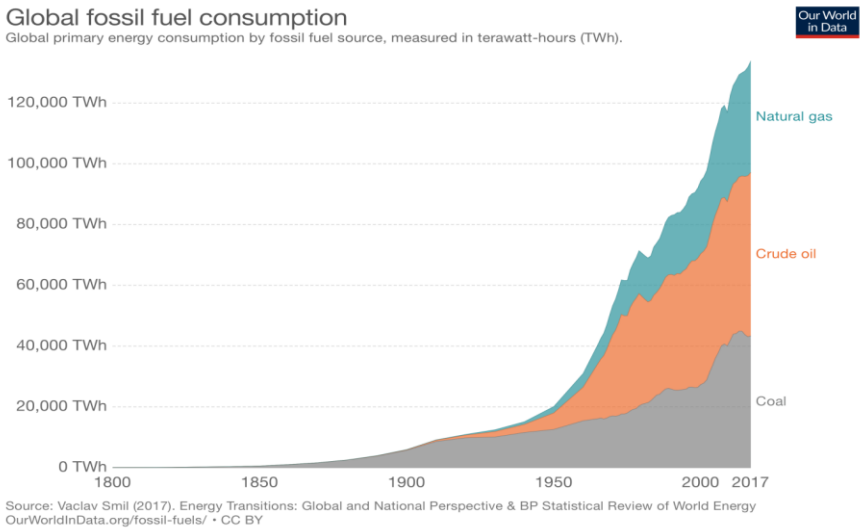


Fig. 1.5. Global fossil fuel consumption [32]

Looking at our future as a community, some attention requires to be paid to how we are going to generate energy in the future. The deposit of non renewable fuel in our earth is limited. For understanding how to properly use the remaining resources - three energy scenarios were provided by the International Energy Agency:

1. The Current Policies Scenario – this will lead to increased stress on almost all elements of energy security and a significant extra increase in carbon dioxide emissions from energy sources.

2.The New Policies Scenario – it includes the governments' announced policies and objectives. According to this scenario global oil demand development will slow but not peak before 2040. China will become the world's biggest single consumer of oil in the 2030s, while Asian developing countries will give half of the growth of natural gas demand by 2040. In general coal consumption will be stable at the level of approximately 5 400 million tons of carbon equivalent and will not repeat the 2014 peak. Coal production in China, by far the biggest producer of coal in the globe, will decrease at an average rate of 0.4 percent per year [2]

3.The Sustainable Development Scenario – it supposes that accelerated clean energy transitions can help mitigate climate change, provide universal access to cheaper energy and meet clean atmosphere objectives. Major changes will occur in most industries, resulting in a 25 Millions of Barrels per Day reduction of the total oil demand by 2040. Gas demand continues to expand in this scenario up to 2025 before stabilization at around 4.2 trillion cubic meters. Gas will be the only fossil fuel that will require more than nowadays in 2040. Coal consumption is falling sharply (by 3.6% per year) and the share of coal in primary energy is supposed to fall below 12% by 2040 [2].

The worldwide energy industry will change considerable over the next 20 years. Energy demand in developing economies can exceed demand in developed countries, but the share of "green" power will be much higher in energy budget due to technological advances. According to this "favorable" scenario of the International Energy Agency, the reserves of fossil fuels reserves will not run out and are likely to remain in the ground after the transformation of energy system of the world.

1.4 Alternative energy sources

The world economy increasingly involves the use of renewable energy sources to substitute partly or completely fossil fuels in the manufacturing of electricity and heat. Energy demands could double or even triple by 2050, with the global population rising and developing countries are expanding their economies.

This has led to the rise of a number of alternative energy sources. While the viability of each can be argued, they all contribute something positive when compared to fossil fuels. Lower emissions, lower fuel prices and the reduction of pollution are all advantages that the use of alternative fuels can often provide.

1. Solar Power
2. Nuclear Power
3. Hydroelectric Energy
4. Wave Energy
5. Biofuels
6. Geothermal Power
7. Wind Energy
8. Biomass Energy
9. Tidal Energy
10. Hydrogen Gas

Solar energy is called renewable or sustainable energy because it will be accessible as long as the sun shines.

Another 4–5 billion years are estimated for the remaining existence of the sun's primary phase. The quantity of solar energy relies on a number of variables, including the degree of cloudiness, the magnitude of atmospheric absorption, and in particular the number of daylight hours at a specified moment of year. Places such as deserts are great locations for harvesting solar energy not only because there is very favorable insolation, but also because there are less productive land uses, such as agriculture or human housing.

Using photovoltaic (PV) cells, frequently called solar cells, we can convert solar energy straight into electricity. Most solar cells are thin silicon purified wafers. These cells can be linked to batteries or they can be linked to current electrical grid systems.

Wind, biomass and biofuel, geothermal, hydro, tides, and waves are the other major renewable energies, which come from the sun.

Wind power is an indirect type of solar energy, as variations in regional heating along with the planet's rotation drive the winds. The average wind velocity differs significantly from location to location, and the strength of the winds differs spatially and temporarily by an even higher quantity. The quantity of electricity that a turbine can produce relies on the length of its blades and the consistency and velocity of the wind around it. Long blades can sweep a big region, meaning they're hit by more wind than smaller blade turbines. They can capture more kinetic energy from the wind. Aerodynamics converts wind power to mechanical power. With significant wind energy penetration into the grid, wind turbines are now integrated into the mainstream generating power source. Commercially installed megawatt capacity wind turbine machines have been operating successfully for many years.

Wind turbines can convert between 12 and 50% of the wind that passes through their blades into electricity, depending on the type of wind turbine and the wind circumstances.

Hydropower is mainly a type of solar power that drives the water cycle of the planet and accounts for the flow of rivers and ocean waves.

Hydropower can produce energy usefully across a wide spectrum of scales, ranging from the world's biggest power plants of any sort— the Three Gorges dam and 22,500 MW power plant in China to a mere 100 W nanoscale hydropower plant – a factor of 20 million times lower. Hydro's most significant use is standard or impoundment hydro power plant, where a dam is built to generate a reservoir. It can be harnessed to generate electricity when the water it includes is permitted to flow out in a controlled way. Not all types of hydroelectric power plants require a large dam, as in a run-of- the-river application, where the flowing water's energy can be captured directly.

Tidal and wave energy is one of form of hydropower. Tidal power, also known as tidal energy, is a type of hydropower that transforms tidal energy into electricity or other helpful power types. Tidal energy is obtained from big water bodies' relative movement. The magnitude of the tide at a location also depends on the local geography of the seabed and coastlines.

Waves are produced in open water whenever the wind speed exceeds approximately 0.5 m/s. The wave crests move in the same direction at about the velocity of the wind that produces them. The longer the wind blows and the larger the water expanse over which the wind blows, the higher the height of the waves stroked by the wind. Waves have lengthy memories and will continue to go in the same direction for days after the wind has stopped blowing until they bump into something.

Biomass is one of the abundantly accessible renewable energy that is spread almost uniformly across the world. It is living or dead plant and animal matter, the waste from such organisms, and the waste from society produced from these organisms. The stored chemical power contained in biomass is called bioenergy.

Bioenergy is organic matter (biomass) power, all biological materials not integrated in (fossilized) geological formations. Biomass can be used as a fuel in its initial form or modified to various types of strong, gaseous or fluid biofuels. Bioenergy comes with traditional biomass (forestry and agricultural residues, for instance), contemporary biomass and biofuels. It reflects the conversion of organic matter into a source of energy; whether for this purpose it is obtained from the natural environment or specifically cultivated.

In contrast to biomass energy sources, *biofuels* make use of animal and plant life to create energy. In essence they are fuels that can be obtained from some form of organic matter. They are renewable in cases where plants are used, as these can be regrown on a yearly basis. However, they do require dedicated machinery for extraction, which can contribute to increased emissions even if biofuels themselves don’t.

Another clean and stable source is *geothermal energy* that is a heat generated and stored in the Earth. Geothermal energy derives from two sources: radioactive decay in the

earth's crust, and heat trickling from the core of the earth through the mantle. Geothermal is an attractive renewable energy because it is "always on" whatever the weather. In the same sense as solar, wind and hydropower, geothermal power is not renewable (the decline of the radioactive elements that supply heat in the earth is limited, no more supply is available to maintain it). The difficulty with creating sustainable geothermal power is that the velocity at which heat travels through strong rock limits the rate at which heat from the red-hot interior of the earth can be sustainably sucked out.

There are two kinds of geothermal power: the power at a normal place on the Earth's crust; and the power at unique hot spots such as Iceland. Geography dictates the worldwide distribution of the most productive geothermal sources, as this energy source is most abundant and available in locations on Earth close the limits of tectonic plate or in significant volcanic regions.

Nuclear power is amongst the most abundant forms of alternative energy. It is based on nuclear fission – a nuclear change in which the nuclei of certain large-mass isotopes (such as uranium-235) are divided into lighter nuclei when neutrons strike. Two or three more neutrons plus energy are released each fission. These numerous fissions within a critical mass of nuclear fuel form a chain reaction that releases a huge quantity of energy that we can use to generate electricity in a nuclear power plant. Thirteen countries relied on nuclear power to produce at least a quarter of their electricity as of 2015 and there are currently 450 plants in operation throughout the world.

Hydrogen is the universe's most abundant component. This component is also discovered in many organic compounds, including the hydrocarbons that make up many of our fuels, including gasoline, natural gas, methanol, and propane - hydrogen also itself can be produced using renewable power. Solar energy and biomass can be used to generate hydrogen more directly in the longer term (sunlight can provide the power needed to generate hydrogen directly or indirectly). Hydrogen may also join electricity as a major energy carrier in the future. An energy carrier is moving and delivering energy to customers in a usable form.

Cities, countries, and federal governments around the globe are putting in place measures to boost renewable energy. More than 100 towns around the world now boast at least 70% of renewable electricity, and others are committed to reaching 100%. Fossil fuels are a finite resource even without climate change, and if we want to renew our planet lease, our energy will have to be renewable.

As the issues that result from the use of traditional fossil fuels become more prominent, alternative fuel sources like the ones mentioned here are likely to gain further importance.

Their benefits alleviate many of the problems caused by fossil fuel use, particularly when it comes to emissions. However, the advancement of some of these technologies has been slowed down due to the amount of investment needed to make them viable.

Conclusion for Chapter 1

In the first chapter of the work, the structure of modern energy consumption of our country and the world analyzed and conclusions drawn about the dependence of the world economy mainly on oil, gas and coal complexes, and therefore it depends significantly on non-renewable energy sources. Having analyzed the consumption of Ukraine, we can confidently say about the country's energy dependence on energy exports from other countries. This dependence and inefficient state policy in this area poses significant obstacles to the economic prosperity of the state, although the introduction of the green tariff in 2009 gave impetus to the development of restoration of energy sources as an alternative to fossil fuels. Modern economic development, in our time, is impossible without the introduction of an energy policy.

CHAPTER 2
FOSSIL FUEL PHASE-OUT CONCEPT

2.1 The history of the idea of abandoning fossil fuels

The nineteenth-century industrial revolution significantly enhanced living standards in many nations, but at the same moment it has unprecedentedly polluted the Earth. The demand for more and more energy to drive our industries, heat our homes and power our transportation and communications is the basis of these changes. The final global signal of environment degradation due to human activity was the Earth's climate change owing to human-caused carbon dioxide emissions.

The human history of fossil fuel consumption can be split into four phases:

1. Human history before the European Industrial Revolution when, in financial activity, fossil fuels did not play such important role (coal has been burned in ancient Greece, Roman Britain, Aztec Mexico and imperial China).

2. From the beginning of the Industrial Revolution in the mid-eighteenth century to around 1870, when coal mining took center role (coal was used as a transport fuel and was the dominant source of energy for locomotives and steamships).

3. From 1870 to the mid-twentieth century, during the second Industrial Revolution, fuelled by coal and to a smaller extent by petroleum and gas.

4. From the mid-twentieth century to the present, when fossil fuel consumption increased and oil surpassed coal as the most widely used fuel.

Nothing has shaped history of mankind more than our energy use. The origin of all energy on the Earth was the Sun activity for most of the civilization period. Agriculture was our primary source of energy before the huge energy returns on both energy and financial drilling investments have made the revolution in fossil fuel the largest event in economic history.

The story of understanding problems started with Swedish scientist Svente Arrhenius ' pioneering work, who realized that industrial processes leading to carbon

dioxide emissions could warm the earth. Thomas Chamberlain's independent research supported this conclusion.

During the 1950s, enhanced science surveys of the atmosphere and the oceans showed that extra carbon dioxide in the atmosphere would warm the world and that the oceans would absorb only about one-third of this.

People became more aware of the importance of the environment during the 1980s. The discovery of the ozone hole in the atmosphere above Antarctica in 1955 showed the worldwide nature of climate change. In this situation, timely international action to prohibit the use of chlorofluorocarbons has been successful in preventing the risk.

Since 1958, atmospheric CO2 concentrations have been continually evaluated. That year, the CO2 measurements were started by Charles Keeling (1928–2005). The atmosphere's carbon content has risen rapidly since it began to be measured. We have raised the CO2 content in the environment from 0.03% to 0.04% since the industrial revolution, and temperatures have risen below a degree Celsius, an increase that has happened at many points in history [6].

Fossil fuels have been the fuel of choice overwhelmingly from the 1970s to the present, especially for developing nations (Fig. 2.1).

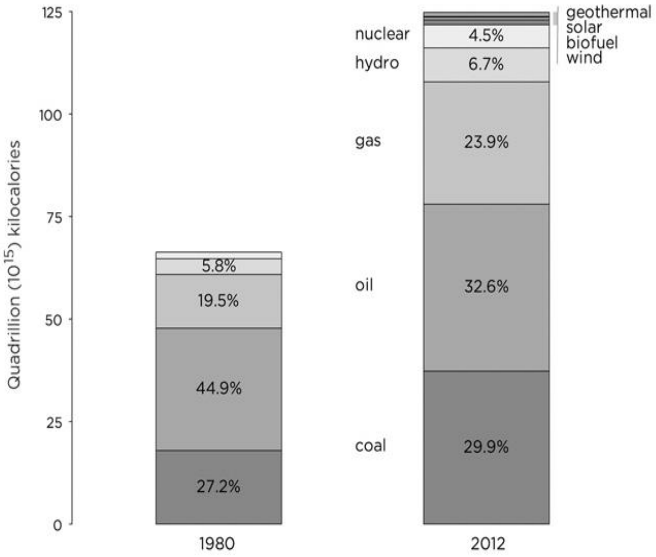
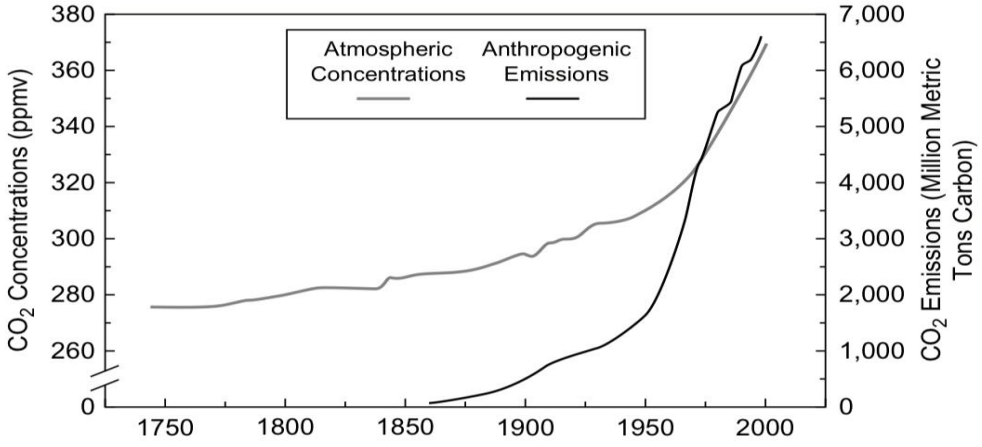


Fig. 2.1. 80 % increase in worldwide fossil fuel use 1980–2012 [56]

In 1977, Amory Lovins, commonly regarded as the leading energy thinker of the 1970s for criticizing fossil fuels and nuclear power and supporting solar power and reducing energy use, stated that we had already been using too much energy. Later, in 1998, Bill McKibben supported the scenario that demanded the reduction of current fossil fuel use by 60% in order to slow down disastrous climate change.

Climate is determined by many natural causes and it is proved to be influenced by human behavior (Fig. 2.2). Extensive measurements have shown that there is a steady increase in atmospheric levels of carbon dioxide, methane and some other gases.



Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.oml.gov/.

Fig. 2.2. The impact of anthropogenic emissions on carbon dioxide atmospheric concentrations

In the 1970s, higher fossil fuel prices concentrated the attention of governments on other ways of generating energy and on energy conservation. State financing for research and development is a good sign of renewable technology's comparative significance. OECD (Organization for Economic Co-operation and Development) nations spent 168 billion dollars on nuclear studies and 22 billion dollars on renewables between 1974 and 1992 [12].

Tanker accidents followed by an oil spill into the ocean made people think. The accidents involving oil tankers are especially severe not only because of the loss of lives, but also because of the severe environmental harm they cause. The first such disaster was on March 18, 1967, when the Torrey Canyon went on to rocks. In southern England and

northern France, this spilled 210,000 barrels of crude oil and spread over 300 km of beaches.

Fossil fuels (coal, petroleum and gas) producing carbon dioxide (CO_2) and other greenhouse gases dominate historical and modern energy systems. By 1960, the world had stepped into the manufacturing of nuclear power. Finally, the renewables of today (contemporary biofuels, wind and solar) are comparatively new, appeared in the 1980s and 1990s. Fig. 2.3 shows the world electricity generation by source (1970-2016), and how the shares of alternative energy and fossil fuels in the global balance have changed.

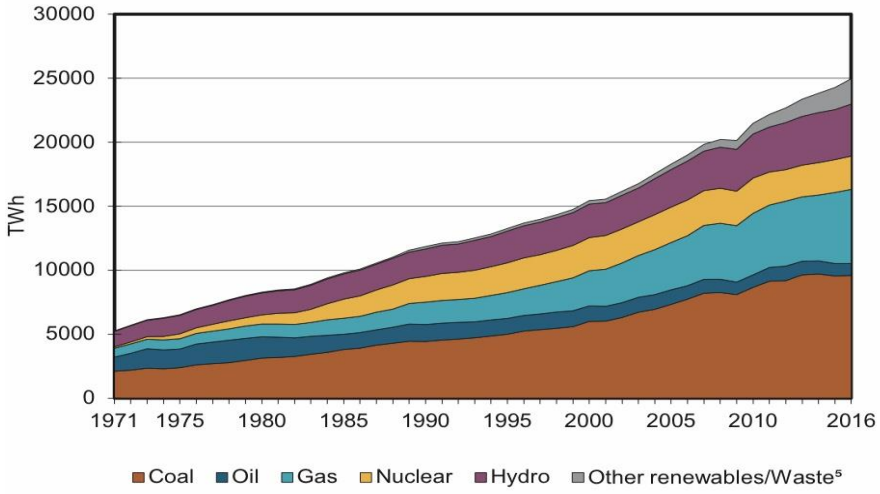


Fig. 2.3. Electricity generation by source in the world [5]

The link between climate change and energy production shows how civilization is moving down a road that has never been trodden before. The world's economy and population grew faster than ever before during the twentieth century, and total energy consumption grew even faster.

2.2 Reasons for the relevance of this trend

Today, understanding our global energy situation is particularly difficult for most people. Of course, in numerous respects and on a regular basis, we all use petroleum and natural gas. These are incredible substances: they are energy-dense and chemically helpful, and they bring huge financial benefits. But petroleum and gas are finite resources,

so it was evident from the beginning that we were actually stealing from the future as we bought and burned them.

The environmental cost from burning fossil fuels on the Earth and its natural systems include: destruction of biodiversity by agriculture and industry; nitrogen cycle disturbance (nitrogen circulation through air, soil and water); and ocean acidification. But the biggest effect is the shift in the chemical composition of the atmosphere by releasing greenhouse gases. Fossil fuel power stations also release many toxic substances into the atmosphere that ultimately fall down as acid rains, killing trees and altering rivers and lakes' ecology. The impacts of these emissions on the atmosphere are accountable for global warming. There are three causal connections between consumption of fossil fuel and the effects of global warming:

1. The burning of particular amounts of fossil fuels generates particular amounts of greenhouse gases;

2. Over time, emissions of greenhouse gasses trigger global warming;

3. The global climate warming is seen and measured by increase in global average temperature and variety of changes in natural phenomena, such as rising sea level, melting ice, weather volatility and climate change.

The world economy now produces more than 100 billion tons of CO2 every three years – which is likely higher than the entire nineteenth-century CO2 emissions. The first decade in this century (2000–2009) was the warmest decade since 1881.

Some estimates of dramatic global warming (and ultimately catastrophic climate change) indicate that CO2's greenhouse impact in the atmosphere will considerably increase the growth of water vapor in the atmosphere, which could cause much more warming than CO2 acting alone. The forecast of catastrophic climate change is based on the concept of extreme weather caused by warming (like the future sea level rise, hurricanes).

The average sea level of the world grew 19 centimeters during the 20th century, mostly due to runoff from melting land-based ice and ocean water expansion as its temperature grew. While researchers are not sure whether climate change will lead to

hurricanes increasing, it is anticipated that hotter ocean temperatures and greater sea concentrations increase their impact.

A number of science research and significant climate models suggest that we increased CO2 concentrations lead to acidification of ocean water, which gradually kills marine inhabitants and entire ecosystems, such as coral reefs.

Coal has major drawbacks. Coal mining is hazardous for human health and many miners suffer from debilitating illnesses like silicosis. The atmospheric pollution created by coal burning is very dangerous for the entire population. Pollution from a coal-fired power plant depends on the quality of the coal, but in a typical case, a coal-fired power plant emits about 11 million tons of carbon dioxide, one million tons of ash and other chemicals each year. The sulfur dioxide released from a coal-fired power plant causes around 25 fatalities per year.

Coal pollutants influence all main body organ systems and lead to four of the top five death causes: heart disease, cancer, stroke, and obstructive chronic respiratory disease. Every step in carbon lifecycle mining, transportation, washing, ventilation, and post-combustion waste management affects human health. Air pollution from coal-fired power plants in the United States is estimated to cause more than 13,000 premature fatalities annually, mostly in the country's coal-dependent localities. Coal pollution causes more than 20,000 heart attacks and 217,000 annual asthma attacks [53].

Industrial energy economies are so deeply dependent on fossil fuels that even the fastest possible growth in wind, solar and other renewable energy industries cannot significantly replace oil, coal and natural gas for at least several centuries. Non-renewable sources such as coal and oil currently generate most of the energy used. This increases the issue of what to do when they become exhausted instantly.

Society is moving away from fossil-fuel-dominated systems one way or another. In electricity generation, the development of renewables is a true and substantial sign of the potential of non-fossil energy production systems. But, some basic problems need to be solved by society in order for fossil fuels abandoning:

• How to sustainably grow food without inputs of fossil fuel and without eroding topsoil or increasingly scarce fresh water supplies;

• How to sustain seven billion individuals without depleting natural resources – including forests, fish, and mineral and metal finite stocks;

• How to restructure our economic system.

We cannot understand precisely what is to come, but it is evident that moving away from fossil fuels is going to be far more destructive of our present economy than almost everyone expects.

The International Energy Agency estimates that the scenario shown in Fig. 2.4, designed to meet expected future energy demand while offering a coin-flip chance of limiting warming to 2°C, would require extra worldwide energy efficiency and generation investment of around $160 billion per year over the current decade, increasing to $1.1 trillion per year by 2035 [15].

The phasing out of fossil fuels on a global stage is now well under way. Proposals are more common today than ever to limit fossil fuels.

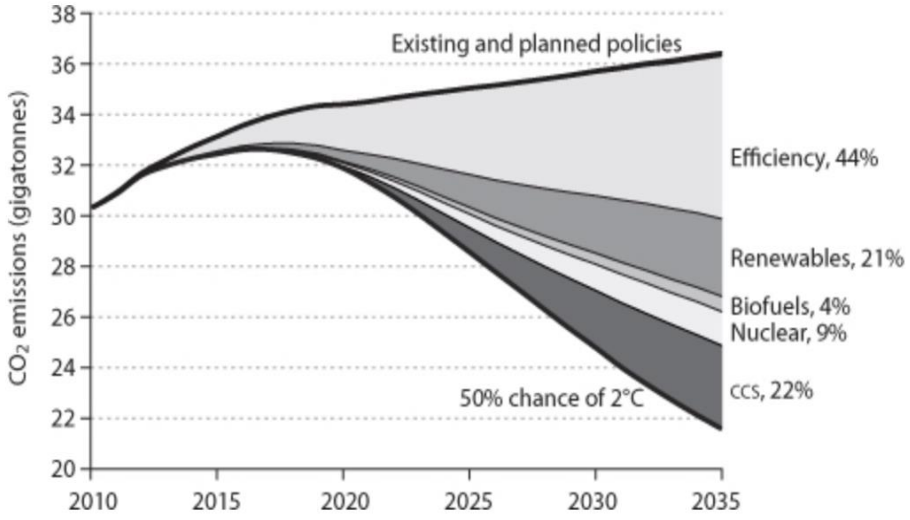


Fig. 2.4. A scenario modeled by the International Energy Agency illustrating what techniques and efficiencies might be needed to reduce emissions by the rate required (the bottom line) compared to previously announced policies (the top line). CCS - Carbon capture and storage [15]

Without some kind of worldwide agreement to restrict the use of fossil fuel, such scenarios (induced above) would not be plausible. It is clear that the only reliable way to remain within permissible global carbon emissions is a global agreement specifically designed for that purpose. But, this scenario is possible and we should to try implementing it for green future of our planet. For instance, according to the Stop Global Warming organization, just turning down the home thermostat in the winter by two degrees and up by two degrees in the summer can reduce carbon emissions by 907 kg a year.

2.3 Legislation and initiatives to phase out fossil fuels around the world

Today, the dominant power source in industrial countries is fossil fuels— coal, petroleum, and natural gas. The next major shift in power sources began in the twenty-first century— from non-renewable fossil fuels to renewable sources of electricity. The nature and pace of this shift will be significantly influenced by government policies.

Several media outlets published an article on June 8th, 2015 that the Canada, France, Germany, Italy, Japan, the UK, and the US agreed to phase out fossil fuel use by 2100 - the initiative called “Parish Agreement”. It is a significant international agreement as we enter a fresh era of climate change because the arrangement shows that nations around the globe can come together to tackle shared issues that will influence us all. This very important agreement entered into force on November 4th, 2016. As of spring 2019, 195 members of “The United Nations Framework Convention on Climate Change” have signed the agreement, and 186 have become party to it [39]. The Paris Agreement is likely the best possible result that could have been accomplished in view of the government parties ' historic impasse.

Three years after the adoption of the Paris Agreement, global climate action is not yet sufficient to limit global warming to well below 2 degrees Celsius and to pursue efforts to limit warming to 1.5 degrees. In order to implement the agreement, members must improve their ambitions and take concrete measures to indirectly contribute to the global objectives also countries should invest the cash in green energy studies and development

that wants to be produced cheaper than fossil fuels. The findings of CCPI (Climate Change Performance Index) 2019 demonstrate the primary regional differences in climate protection and efficiency in the 56 nations assessed and the EU. The map shows the aggregated results and overall performance of countries including Ukraine (Fig. 2.5). This year Ukraine took the 18th place in the ranking (with medium rating), leads Sweden, Morocco and Lithuania. However, no nation is doing enough to avoid harmful climate change [23].

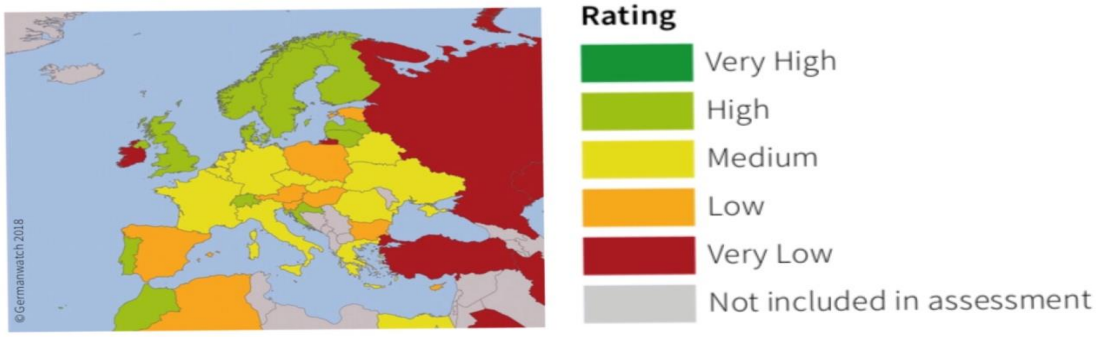


Fig. 2.5. The ranking by the aggregated performance of 14 indices in the four categories of "GHG Emissions," "Renewable Energy," "Energy Use" and "Climate Policy" [23]

Coal continues the single biggest source of energy to produce electricity globally, cheap, plentiful and the most polluting of fossil fuels. The disadvantages of coal are so serious that our dependence on fossil fuels must be reduced.

In collaboration with 24 domestic and regional governments committed to phasing out coal, the United Kingdom and Canada jointly initiated a successful initiative called the Powering Past Coal Alliance. Launched at the UNFCCC Conference of the Parties in 2017, they are committed to "phasing out current unleashed coal generation and implement a moratorium on fresh coal generation without operational carbon capture and storage". According to the “phasing out” members must carry out full implementation by:

- by 2030 Organization for Economic Co-operation and Development countries;
- by 2040 China;

- by 2050 Rest Of World

Further shown two examples of countries and their initiatives of coal's phase out:

The world's leader of coal is *China*. The country consumes half the world's coal. Spurred by public outcry about air pollution, the country is now also the world leader in installing solar and wind power, and its central government has attempted to slow down development of coal-fired power plants.

Germany is European Union's largest greenhouse gas emitter. Coal power in the country still accounts for about a third of electricity generation. In January 2019, Germany's plans to phase out and shut down the remaining 84 coal-fired plants on its land by 2038 are initiated by the German Commission on Growth, Structural Change and Employment [39].

Oil (petroleum products) products assist us do a lot of stuff. We use them for fueling our aircraft, vehicles, and trucks, heating our homes, and making products such as drugs and plastics but over the years there has been enhanced concern about the oil industry's environmental impacts.

About 10 nations and approximately twenty cities around the globe have suggested banning future sales of passenger cars powered by fossil fuels such as petrol, liquefied oil gas and diesel. There are some of these initiatives:

• The strategy of *Japan* is based on the strong belief that hydrogen can be a crucial reaction to its problems of energy and climate. The strategy mainly seeks to attain hydrogen's price parity with competing fuels, such as transportation gasoline and electricity generation liquefied natural gas.

• The *Irish* government is planning to prohibit the sale of new petrol and diesel cars as part of a significant environmental protection policy by 2030.

• *France* also said that by 2040 it would prohibit petrol and diesel car sales. Initiatives include prohibiting further licenses in France and its overseas territories for oil and gas exploitation [39].

• By 2025, only 100% electric cars will be sold by *Norway*, eliminating petrol-based vehicles.

Other world policy five alternatives to encourage a shift to renewable energy for fossil fuels phase out include:

1. Research and development for energy;

2. Tariffs for feed-in;

3. Renewable sources subsidies, including favorable tax provisions and terms of loans;

4. Objectives of renewable energy;

5. Improvements in efficiency and standards.

There is an urgent need for new strategies in this very different world. The climate change side's main focus— and the only severe reason for optimism— may lie with fresh and emerging technologies. With very little basic technical change, the energy industry is shifting from a century to one where almost every dimension is being deeply disrupted. The future of everybody is at risk. We need all nations to take climate ambition much more seriously.

2.4. Current state of implementation of the alternatives to fossil fuels

Over the centuries, engineers and scientists around the world have shown endless ingenuity in reducing the amount of energy needed to achieve a specific outcome. These allowed us to become richer by extracting more utility from each available energy unit. We create energy more productive when we enhance energy efficiency, because each drop of oil or lump of coal can do more work. Alternative sources of energy, efficient techniques and voluntary carbon savings are one way of reducing fossil fuel use and clean atmosphere.

A global shift from fossil-fuel energy to renewables use is not an easy task, as it depends on new techniques, enabling low-cost wind and sun energy capture and transfer to human markets. In terms of renewable power use, three nations – China, the United States, and Germany – are ranked number 1, 2, and 3 on the globe. Together, China and the US have invested half the total worldwide in the development of renewable energy. But, in

term of percentage the most “green” are Norway and Iceland. Norway produces 99% of its energy from hydropower, while Iceland obtains 100% from renewable sources — both hydropower and geothermal. With non-hydro renewables as the manual, Spain, Denmark, Germany, and the United Kingdom seem to be the world leaders in the shift to renewable energy as outlined in Table 2.1. Denmark's wealth development decoupled from fossil fuel development as the country struggled to create a fresh economic strategy.

Table 2.1.

Countries with high renewables transitions (non-hydro renewables) [14]

Country	Renewables in Power, 2015	Goal
Spain	47 %	70% by 2030
Denmark	40 %	100% by 2035
Germany	32 %	40% by 2020
United Kingdom	24 %	30% by 2020

BNEF (Bloomberg New Energy Finance) has conducted a detailed assessment of the worldwide and regional trends (Fig. 2.6). Its evaluation is that renewables will become the dominant source of energy on the globe by 2040, replacing coal and gas. Over the previous few centuries, prices for fossil fuels, particularly oil and gas, have been highly volatile, and investors can now see a more reliable renewable energy choice.

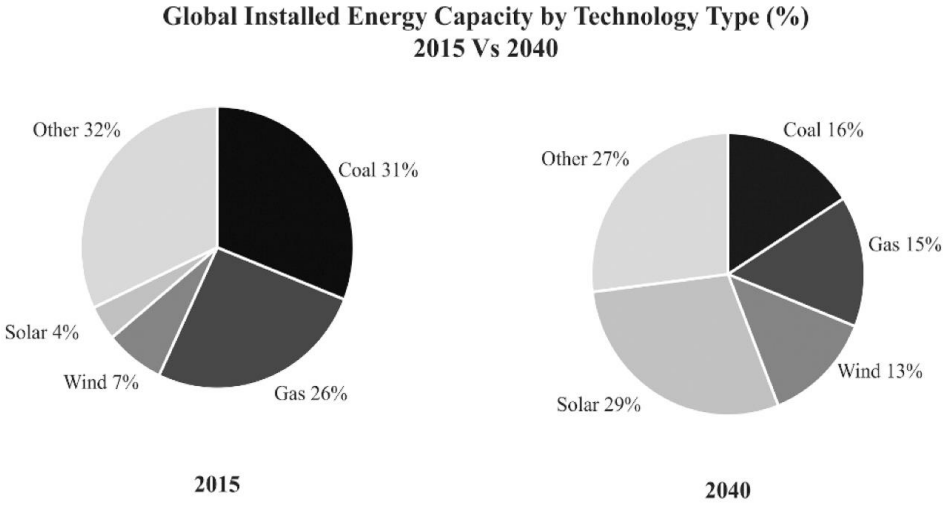


Fig. 2.6. Globally installed energy capacity by type of technology, demonstrating predicted development in renewables at the cost of coal and gas in 2015 versus 2040 [14]

The decision for the world is simple: invest in the future or in the past [52]. There are some different ways, technologies and world innovations for abandoning fossil fuels and clean environment:

1. Solar photovoltaics and Wind turbines as new power generation sources;
2. Zero net energy houses as a way to reduce domestic energy consumption;
3. Electric vehicles as a mean to reduce direct fuel use on transport;
4. Biomass as a substitute of traditional fossil fuels;
5. Carbon capture as a mitigation of previously released and future CO2;
6. Investments in new renewables technologies as an approach to provide future demand growth;
7. Energy-efficient techniques as a fundamental element of energy safety.

Every day the sun shines, offering nearly unlimited, clean and free fuel at a cost never changing. The International Renewable Energy Agency has already credited 220 million to 330 million tons of annual carbon dioxide savings to *solar photovoltaics***,** and it is currently less than 2% of the worldwide energy mix [52]. In Germany, 1.4 million solar systems have been built with a combined generating ability of 36,000 megawatts, more than a quarter of the world's capacity. The solar share of Germany grew to almost 7% in the first 11 months of 2014 [53]. Another ambitious domestic solar target comes from Saudi Arabia, where some 41,000 megawatts of solar power are planned to be developed by 2032. They could supply up to two-thirds of Saudi Arabia's energy if these crops were in service today [53].

Today, almost 4% of global electricity is supplied by 314,000 *wind turbines*. The six major countries for installed wind capability are China, the U.S., Germany, Spain, India, and the United Kingdom, collectively accounting for 76% of the complete globe. Ten million homes are powered by wind in Spain alone, China alone brought nearly 31 gigawatts of new capacity and Denmark now provides wind energy to more than 40% of its energy requirements. Power lines are being built to connect remote wind farms to high-demand areas. Although wind power continues to be used for agricultural purposes, including pumping water, it is by far the dominant application for electricity generation.

A net construction (house) with *zero net energy* consumption is the one that produces as much energy as it uses a year. It can produce surplus electricity in a few months. Net zero neighborhoods, districts and communities are being intended and built, such as the affordable housing project Kaupuni Village in Hawaii and the solar city Sonnenschiff in Freiburg, Germany, which generates four times the energy it consumes.

Unlike the manufacturing, commercial, and residential industries, the economy's transportation sector is almost completely dependent on one source of energy: oil. Most of the world's oil consumed is for transportation. However, transport can phase out oil quickly. There are three alternatives: electric vehicles and renewable fossil fuels - biofuel and renewable gas.

The *electric vehicle* (EV) is increasingly the preferred choice. Worldwide government programs encourage the purchase of electric cars. From 2014 to 2015, sales jumped, from 315,000 to 565,000 electric vehicles [52]. Two-thirds of the world's EV revenues are in the three biggest passenger car markets: the US, China, and Japan.

Instead of releasing fossil-fuel carbon that has been far below ground for eons, *biomass* energy generation trades in already circulating carbon, cycling from atmosphere to crops and back again. At current, more than any other renewable energy, biomass fuels 2 percent of worldwide electricity manufacturing. Bioenergy is 20 to 30% of the domestic generation mix in some countries – including Sweden, Finland, and Latvia – nearly supplied completely by trees. In China, India, Japan, South Korea, and Brazil, biomass energy is on the increase.

Finland is one of biomass power's world leaders. The primary drivers of biomass use in Finland are its absence of alternative energy sources, cold weather, and the availability of biomass waste from the large forestry, wood products, and paper sectors in the country.

Fossil fuel regulation and alternative power advancement are strongly linked. Every policy that puts pressure on carbon emissions brings investment and alternative implementation. *Carbon capture* - both traditional CCS for point sources such as power

plants and more futuristic ambient air capture technologies for removing carbon directly from the atmosphere – is the key to unlocking international progress on climate change.

Carbon capture includes trapping and isolating carbon dioxide from its source of emissions to a storage place (generally deep underground). This implies that we can possibly capture surplus CO2 from the power plant and create greener energy. The UK's greatest carbon capture project will quickly prevent thousands of tons of manufacturing emissions from contributing to the climate crisis. A chemical plant in Cheshire (UK) could keep 40,000 tons of carbon out of the air every year within 2 years. In the aggregate, the government is planning to spend £26 millions to spur "vital" carbon capture initiatives if the United Kingdom hopes to achieve its objective of reducing carbon emissions to net-zero by 2050 [27]

The expansion of renewable energy, such as wind and solar power, is a main factor in enhancing air quality and opportunity of abandoning fossil fuel. Last year was the eighth in a row in which worldwide *renewable power investment* surpassed $200 billion – and the world has invested $2.9 trillion in green power sources since 2004. Fig. 2.7 shows the most “popular” renewable technologies for investments in the world. Now, China, Europe and the U.S. are the top three markets for renewables investment.

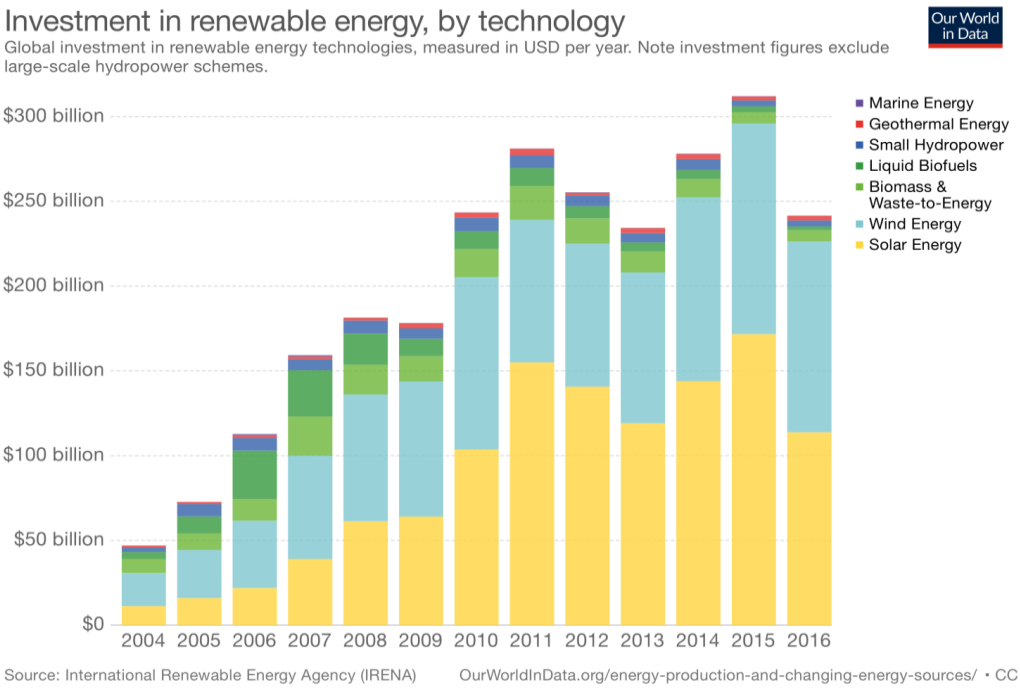


Fig. 2.7. Investment in renewable energy by technology [33]

To date, the 21st century has been characterized by significant modifications in our understanding and use of energy. Energy efficiency is an important component of fuel economy. *Energy-efficient techniques* can be discovered in all areas of the energy transformation chain: from primary energy resource exploration and manufacturing to electricity generation and oil refineries to electricity grids, to end-use in sector, buildings and transport.

A broad variety of sectors benefit from energy effectiveness:

- Residential;
- Buildings;
- Transport;
- Industry

Implementing energy-efficient interventions at all phases of the supply / demand chain could considerably decrease the adverse effects of energy use on environment and human well-being, and boost the supply of primary energy resources while at the same time achieving maximum output advantages from the energy available.

Germany is the world's most energy-efficient country. Germany's world ranking is due to the reality that German leaders agreed 15 years ago to gradually remove the nation from fossil fuels and nuclear power. Italy is close to Germany in the ranking. This is because Italy intends to boost renewable energy generation from all renewable sources to 26 percent of all electricity generated by 2020, according to its domestic energy strategy. They have also decreased the use of coal and oil.

Conclusion for Chapter 2

In the second section of this work, the concept of fossil fuels phase-out was considered as an important component in understanding the reasons for the need to change the main fuel components of the energy complex. The history of the idea was examined by stages: from the beginning of industrial revolution - the starting point of the global use of combustible minerals to the modern problems associated with their uncontrolled burning.

The reasons that prompt the world to pay attention to this problem are emissions of pollutants and greenhouse gases, leading to changes in climate, biodiversity loss and health threats.

The need to introduce legislative initiatives regulating this industry is shown for both Ukraine and the whole world. An important step for the world community was the signing of the “Paris Agreement”, which entered into force in 2016 and aims to phase out fossil fuels. Following this trend, many countries have developed their own initiative projects.

CHAPTER 3
PROSPECTS FOR REJECTING FOSSIL FUELS IN UKRAINE

3.1 The current level of energy consumption and energy supply in the country

Ukraine has about 45 million individuals making it the 32nd most populous country in the world. Our country consumes about 182 TW*h/year of electricity from different sources. Ukraine oil products are almost exclusively used in the transport sector, while are not exploited in the electricity and heat generation activities.

Energy and electricity have become key elements and drivers in the modern world. Understanding energy demand and supply trends is important for energy policy making. The present power mix in Ukraine depends strongly on fossil fuels and nuclear power, which together account for more than 90% of the country's power supply. At the moment, the complete share of renewables is around 8% (approximately 6% is hydropower) (Fig. 3.1).

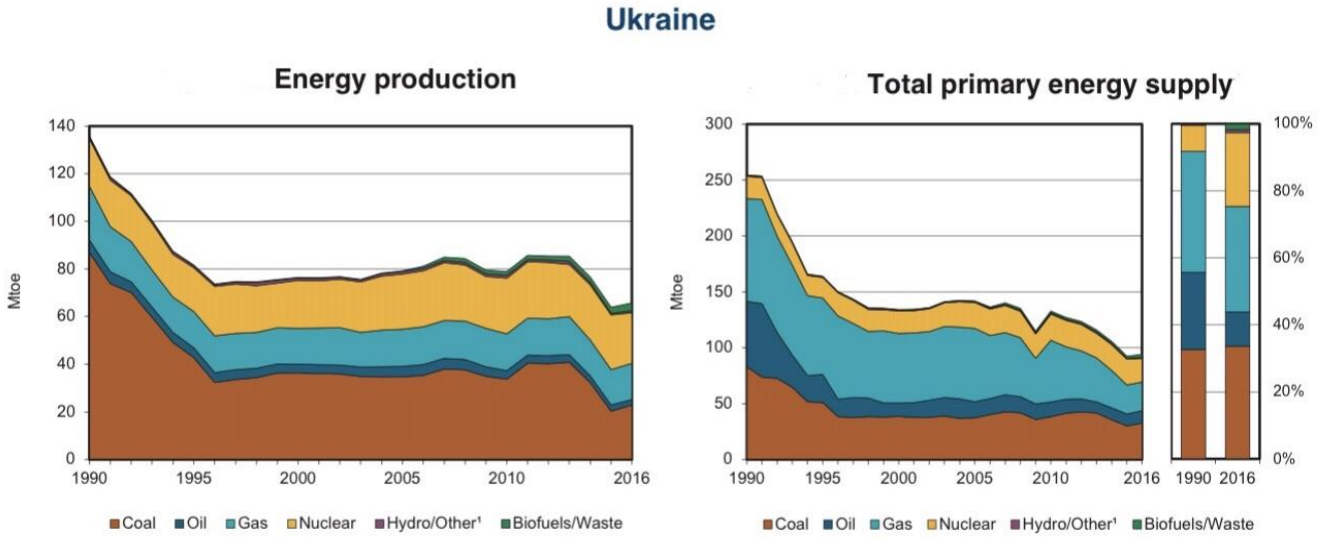


Fig. 3.1. Total energy productions (left) and total energy supply (right) in Ukraine [5]

It is well known that electrical-power generation is the key factor for advances in industry, agriculture, technology and the level of living. The electrical energy is essential

for individuals to enjoy a high quality of life in our high-energy community.

In general, electricity can be generated from non-renewable and renewable energy sources. There are three major industries of electricity generation in Ukraine:

1. Nuclear power plants;

2. Thermal power stations (dominant use of coal);

3. Hydroelectric power stations

Nuclear power in our country is the most important source of electricity generation – it provides 45.5% of electricity, while coal gives 38%, gas generation 9.6% and the rest is based on renewable sources, mainly on hydropower plants – 5.9%) (Fig. 3.2).

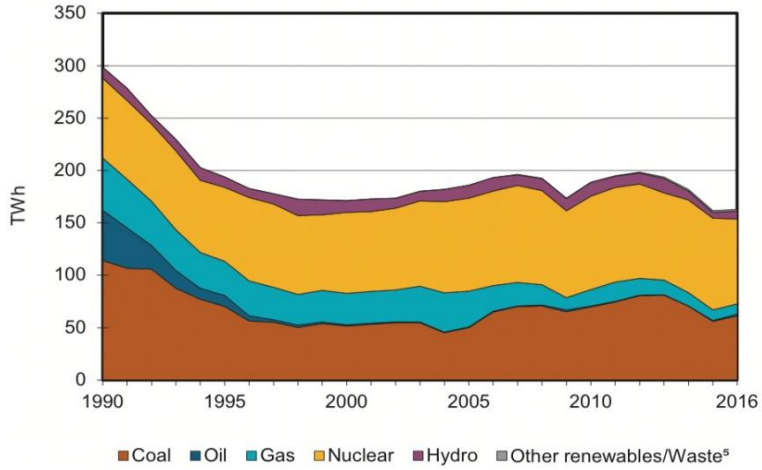


Fig. 3.2. Electricity generations by source in Ukraine [5]

Ukraine depends highly on *nuclear power* – it has 15 reactors that generate about half of its electricity. In the long run, nuclear power will stay competitive relative to other kinds of electricity generation in Ukraine owing to its economic efficiency. The Ukrainian energy strategy to 2030 was updated in mid-2012 and a fresh nuclear capability of 5000 to 7000 MW (megawatt electrical) was suggested by 2030, costing some $25 billion. The new government created in 2014 verified these goals and said Ukraine intended to integrate with the European electricity grid and gas network in order to make the nation part of the European energy market by 2017. In August 2017, another update of the power plan placed the nuclear share of electricity at around 50% by 2035, with hydro-13% and other renewable at 25% [34].

A *thermal power* station is a power station in which heat energy is converted to electric power. As of 2016, heat generation is an absolute champion in terms of installed ability, with a share of 47.6% of national assets, while these plants cover more than 30% of energy manufacturing [26]. Their overall working principle includes the combustion of pulverized coal to achieve high-energy steam that puts turbines generating energy into practice.

Hydroelectric power plants take the third position after heat and nuclear energy in Ukraine's energy complex. The Ukrainian HPS' total installed capacity is presently 8% of the country's combined energy system's total capacity. The largest Ukrainian hydroelectric power station is “DniproGES”, the capacity of all units of which is 1539.8 MW [26].

Ukraine is partially resourced with its own traditional fuel and electricity, so it requires substantial fuel and power imports. Over the previous few years, the share of imports in Ukraine's complete main power supply has been around 38%. Table 3.1 shows total primary energy consumption and supply and clearly show the dependence of Ukraine on imported fuel.

Table 3.1.

Total primary energy supply and consumption in Ukraine (thousand tons of oil equivalents) [5]

Supply and consumption	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal /Solar /etc.	Biofuel /Waste	Electricity	Heat	Total
Production	2869	2304	-	15175	21244	660	124	3348	-	599	66323
Imports	10617	527	9155	8809	-	-	-	38	7	-	29152
Exports	-495	-25	-24	-	-	-	-	-554	-329	-	-1427
Intl. marine bunkers	-	-	-	-	-	-	-	-	-	-	-
Intl. aviation bunkers	-	-	-157	-	-	-	-	-	-	-	-157
Stock changes	-547	0	-586	1620	-	-	-	-1	-	-	492
Total Primary Energy Supply	32450	2806	8387	25603	21244	660	124	2832	-323	599	94383

The new energy strategy for Ukraine was introduced in August 2017. The approach sets out three execution phases: by 2020, by 2025 and by 2035. Completing a reform of the gas and electricity industries, increasing national output of natural gas, developing the coal market and reforming coal mining in particular is scheduled during the first phase. Renewables are expected to account for 8% of main power production by 2020. The final phase of execution of the strategy needs Ukraine to introduce a domestic greenhouse gas trading scheme, reduce emissions and boost the share of renewables in total main power production to 25% [20].

In recent years, the use of renewable energy sources has become more wide- spread in Ukraine, but today, Ukraine's "green" energy is still in the process of development. By 2035, Ukraine is planning to increase the RES (renewable energy systems) share by 7 times. Current technological set-up and relative volumes of RES in Ukraine, however, do not allow thermal power generation capacities to be completely replaced by renewable energy.

The trend towards rapid growth rates of connecting renewable energy facilities to Ukraine's UES (United Electrical Energy System) electrical networks is stipulated in Ukraine:

1. Development of the RES (Renewable Energy Systems) market and relevant global trends;

2. Presence of support for new RES objects through the green tariff (due to this tariff Ukrainian solar power generation industry developing, the Fig. 3.3 shows this dependence).

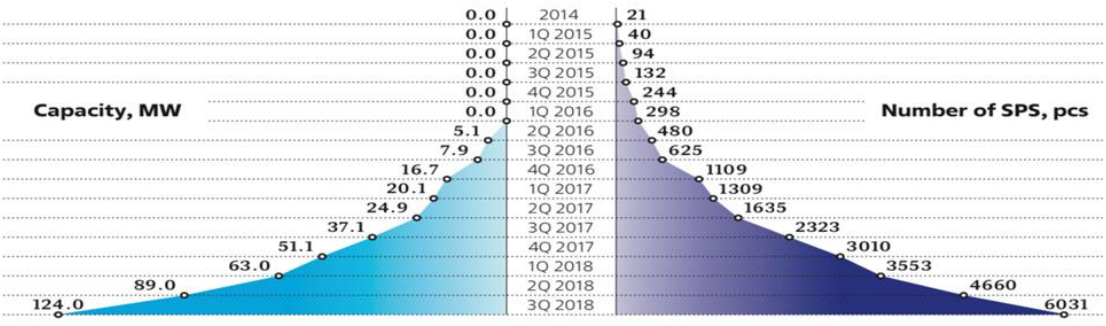


Fig. 3.3. Number and general capacities of solar power station plants working under the "green" tariff [19]

Due to the political and economic difficulties that Ukraine has faced in recent years, energy efficiency and the development of renewable energy sources have become a matter of energy sovereignty and the country's wider security. Ukraine has a strong ability to exploit the energy industry transformations by adopting a large share of renewables development strategy that can benefit both the economy and the environment. Our country should not only concentrate on current priorities, but also address problems that will shape its future transformation, taking worldwide energy trends into consideration.

3.2 Availability of fossil fuel in Ukraine

Ukraine was estimated to possess natural gas reserves of 1.1 trillion cubic meters in 2017, which is 0.5% of global gas reserves. It is estimated that Ukraine's natural gas reserves could be even several times larger. In particular, this applies to unconventional gas (shale gas, methane carbide, tight gas sands). Total proved reserves of coal in Ukraine at the end 2017 were 34,375 billion tons, which is 3,3% of global coal reserves. Proved Reserves of oil are: 395 million bbl (barrel) [21].

Historically, Ukraine has been a leading producer of *oil* worldwide. Most of its petroleum reserves, however, are now exhausted. The Carpathian, Dniprovsko-Donetsky (Dnieper-Donets) and Pry-chornomorsko-Krymsky areas still contain oil and natural gas.

Ukraine has the third largest confirmed *natural gas* reserves in Europe, despite the decline in domestic extraction. At the same time, Ukrainian gas deposits have increased by more than one-third over the past decade when measured according to international methodology. The reserves currently in place mean that Ukraine can significantly improve its production. Up to 80% of confirmed gas reserves are located in the region of Dnieper-Donets (mainly in the provinces of Kharkov and Poltava), where 90% of Ukraine's gas is extracted.

Active work is underway to study the prospects for unconventional hydrocarbon deposits, including *shale gas*. According to the estimates of the "Ukrnaukageocenter", the

volume of shale gas in Ukraine is 15.3 trillion m^3, of which 9.4 trillion m^3 accounts for the Eastern oil and gas producing region and 5.9 trillion m^3 - to the West [36].

Coal bed methane is a natural gas in seams of coal that is extracted without coal mining. Main sources of Ukrainian methane coal seams are situated in the coal basins of Donetsk and Lviv-Volyn. Total estimated reserves of methane coal seams in the country are 12-13 trillion m^3, of which 3-3.5 trillion m^3 are methane reserves for recoverable coal beds [37]. Coal bed methane is not presently being collected in Ukraine, but the use of contemporary technology for hydrofracking could likely make methane extraction from industrial coal beds a reality in the near future.

Ukrainian *coal* is renowned for its high quality throughout the world. Most of these high-quality coal reserves are in the Donets'k coal basin, which has an area of over 50,000 km^2 rich in coal reserves. Most of the reserves consist of thermal coal, coking coals account for about 30%. Difficult mining and geological circumstances characterize the deposits of coals. Over 60% of total coal reserves are buried at a the depth of more than 900 m, with the maximum depth of more than 1500 m. Currently, the current state of the coal mining industry and its position in our country are of topical interest due to the geopolitical situation in Ukraine and, in fact, is an open issue. Under these circumstances, coal mines subordinated to the Ministry of Energy and Coal Industry of Ukraine reduced their coal production by 62% in 2015 (Fig. 3.4).

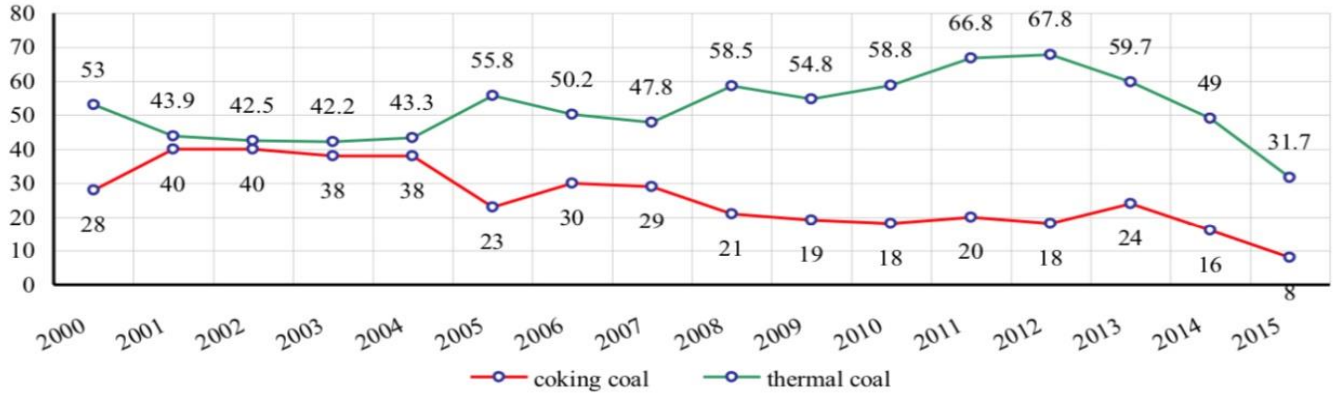


Fig. 3.4. Dynamics of coking and thermal coal production in Ukraine in 2000 – 2015, mln tons (source: V. Snihur, D. Malashkevych, T. Vvedenska [17]

Peat is a significant energy opportunity for Ukraine. Area of peatlands in Ukraine is 10 000 square kilometers, over half of these are situated in the north of Polesia. The other primary peat deposits region is the Dnieper Valley, especially on the eastern side of the river. Excavated peat is used mainly as a local fuel (peat briquettes) in housing and rural regions. Peat briquettes are a worthy alternative to traditional fuels, such as diesel fuel, coal, gas, firewood and sawdust briquettes, as the price of thermal energy produced from the briquetted peat is 10-30% lower.

Long before many other nations – almost 250 years ago – Ukraine started manufacturing of industrial petroleum and gas. Annual gas manufacturing achieved its peak of nearly 70 billion cubic meters in 1975, more than twice the present annual total gas consumption in Ukraine (Fig. 3.5). In the twentieth century, Ukrainian oil and gas industry boomed. This boom started when the Dashava gas field, ranked the biggest in Europe at the moment, brought the first gas pipeline into service. The natural gas industry in Ukraine has evolved at rates that have made it famous across Europe and around the world.

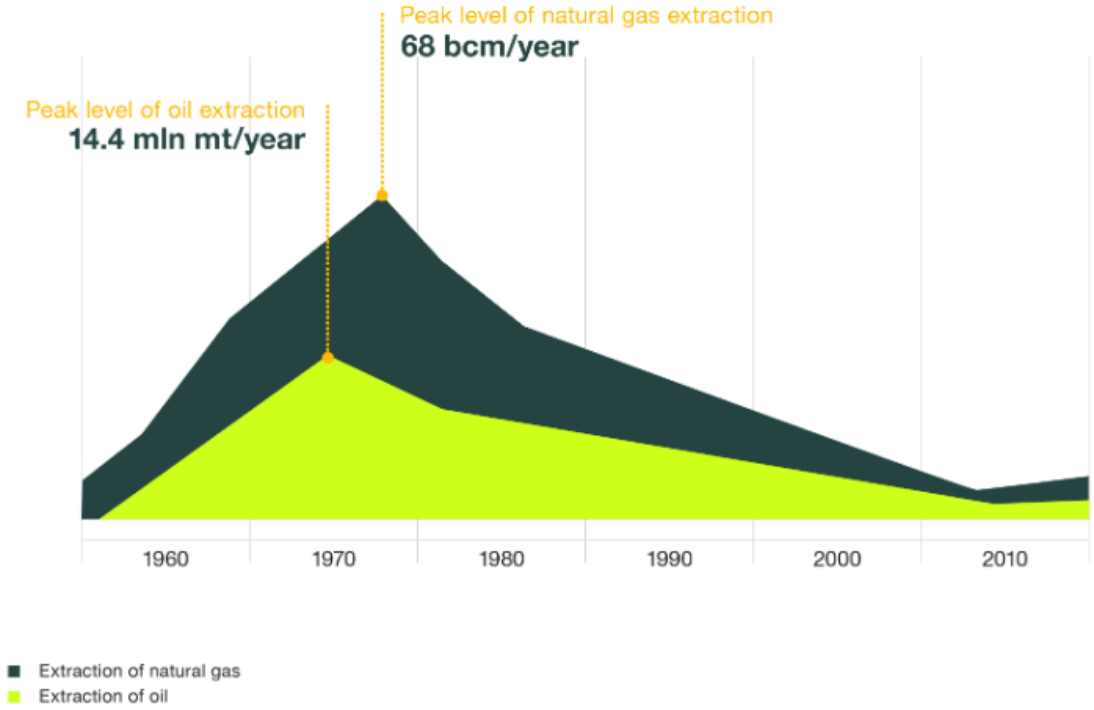


Fig. 3.5. History of oil and gas extraction in Ukraine [57]

Over the 20 years of independence, a lot of minerals have been extracted from the bowels of Ukraine, but the country has retained a high potential of a mineral resource base. Table 3.2 shows volume and number of years with there will be enough reserves for our country (approximate calculations, may change over time).

Table 3.2.

The confirmed amount of energy resources in Ukraine and number of years for which there will be enough reserves at current production levels [26]

№	Energy Resource	Volume	Number of years for which there will be enough reserves at current production levels
1	Gas	0,6-1.1 trillion cubic meters	33
2	Coal	34,375 billion tons	834
3	Uranium	0,1 mln. tons	115
4	Oil	395 million bbl	25

Scientific research significance is clarified by Ukraine's critical energy reliance on external energy sources. Ukrainian dependence on the import of expensive energy resources leads to considerable socio-economic problems. The nation relies highly on imports to satisfy its energy requirements, particularly for oil and gas.

Ukraine needs gas self-sufficiency by 2020, which implies 35% more output. Under this program, as quickly as 2020, the quantity of gas obtained will rise from the present 20 billion cubic meters to 27 billion cubic meters [35] (Fig. 3.6). In combination with increased energy efficiency, this would allow Ukraine to become self-sufficient in terms of gas production and even export gas in the years to come. Government forecasts indicating rise in gas extraction in such a short time are not very realistic, but it seems likely that manufacturing will be able to achieve a level that will make Ukraine independent of imports in the next few years.

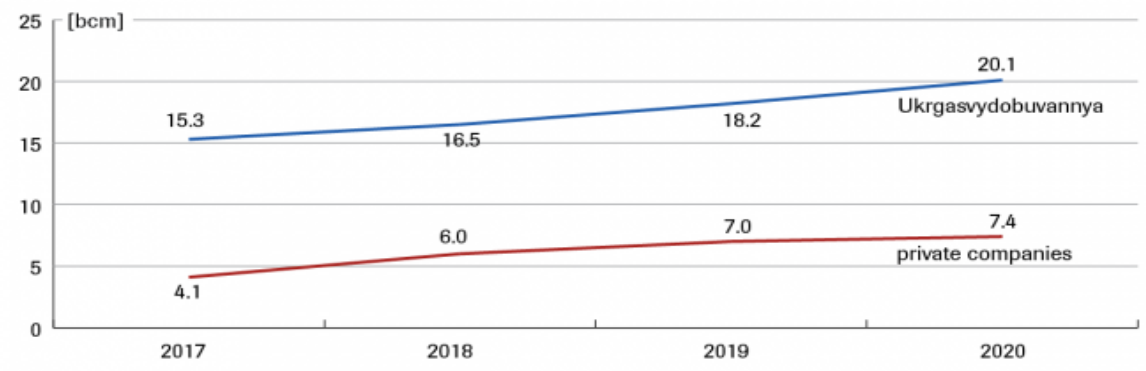


Fig. 3.6. Ukraine gas extraction forecast for up to 2020 [35]

Still, the economy of Ukraine continues to be Europe's most energy-intensive. The country has to import raw materials, primarily fossil fuels, with such enormous demand for energy. Data from the International Energy Agency (2018) show that 75% of the diesel and heating oil consumed, 40% of the natural gas and 35% of the coal are imported because the current domestic production cannot meet the requirement. Figure 3.7 shows current self-sufficiency in Ukraine.

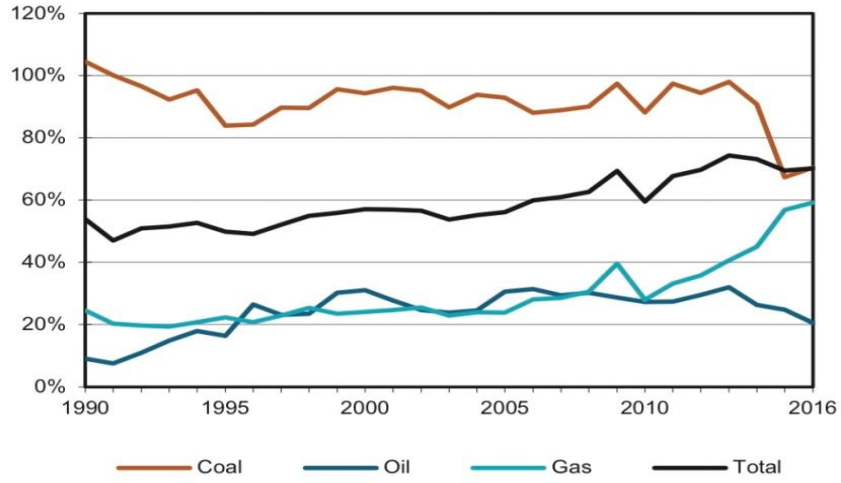


Fig. 3.7. Energy self-sufficiency in Ukraine [5]

While achieving energy self-sufficiency remains unrealistic, this does not mean that Ukraine should sit idly by in the face of the economy’s vulnerability to oil and gas prices spike. Self-sufficiency could do by developing its shale gas reserves, extracting coal bed methane and improving its own existing gas production wells, but in the future priority sources must based on renewables.

3.3. Ukraine's ability to meet its energy needs through alternative energy sources

Over the last years, Ukraine has significantly improved its position in the field of renewable energy development. Significantly increased production of wind, solar and bioenergy and gives hope for the possibility of future based on renewables. Increasing the use of renewable energy sources and alternative fuels is an important part of Ukraine's strategy for saving on traditional fuel and energy resources and reducing the impact on the environment. We can define three main drivers for using renewable energy: energy security, economic impacts, and CO2 emission reductions.

The main direction of world energy development is already visible: the world is entering the phase of an energy transition to widespread use of renewable energy sources and the displacement of fossil fuels, under the influence of changes in energy policy and the development of new technologies. How easily will that happen in Ukraine? There are many forecasts for the development of the renewable energy industry in Ukraine – it is possible to consider several of them (Table 3.3):

- According to resolution of the Cabinet of Ministers of Ukraine in 2017 “Security, Energy Efficiency, Competitiveness” strategy the total estimated capacity of renewable energy sources in our country including nuclear by 2030 its approximately 45,5 Mtoe, without nuclear power - 15,5 Mtoe [41].

- For the same year, REMAP “Renewable Energy Prospects for Ukraine” gives a more optimistic forecast with the maximum technically achievable use of renewable energy sources potential. This international agencies program determines the renewable energy potential of different countries including Ukraine [44].

- National Institute of Technical Research in Kiev gives the most positive outlook 80 Mtoe based only on renewables. This potential is quite significant, technically attractive in the context of significant increase in prices for traditional energy resources in Ukraine [45].

Table 3.3.

The structure of GPES of Ukraine estimated capacity to 2030, Mtoe. [41], [44], [45]

Description of primary energy source	2025 (Cabinet of Ministers of Ukraine strategy)	2030 (Cabinet of Ministers of Ukraine strategy)	2030 Technically achievable potential (According to REmap (IRENA))	2030 Technically achievable potential (National Institute of Technical Research, Kiev)
Coal	14	13	-	-
Natural Gas	27	28	-	-
Oil	8	7,5	-	-
Nuclear Power	28	27	-	-
Biomass, biofuel and waste	6	8	21,7	31
Solar and wind power	2	5	19,2	34
HPP	1	1	7	3
Geothermal Energy*	1	1	8,4	12
Total	87	91	56,3 (only renewables)	80 (only renewables)

The use of renewable energy sources is a priority way of building sustainable energy systems in Ukraine today. Now it is not only wind, solar, hydro and biomass that get attention. Investment projects efficiency in renewable power depends on forecasting electricity generation of any renewable energy source on a specific territory. Fig. 3.8 shows current situation of renewable energy sources prevalent in different regions of Ukraine and clearly shows the predominance of solar energy in the renewable industry over others.

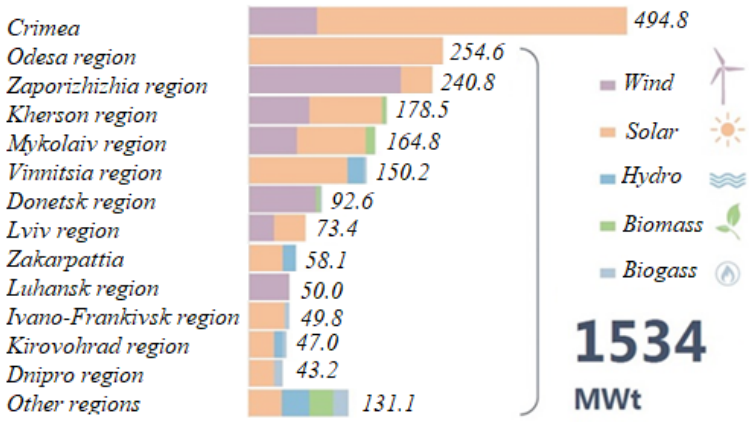


Fig. 3.8. Production of renewable energy by region and source in Ukraine 2018 [42]

In this section, 6 possible ways of developing alternative energy to replace fossil sources will be considered:

1. The increase in nuclear energy to the maximum;
2. Capacity building for wind energy;
3. Solar Energy Capacity Building;
4. The use of geothermal energy;
5. Bioenergy use;
6. The introduction of "energy mix" from renewable energy sources.

Nuclear power is already a known source of low carbon power generation. Whether or not it's an actual source of renewable energy is up for discussion. In 2018, the total production at nuclear power plants in our country amounted to 21,244 Mtoe - 22% of the total energy demand of our country (94,383 Mtoe) [5]. These 22% is provided by 4 nuclear power plants operate in Ukraine:

- Zaporizhzhya NPP - 6000 MW
- Rivne NPP - 2835 MW
- South Ukrainian NPP - 3000 MW
- Khmelnitsky NPP - 2000 MW [46]

As for the full ability to meet of Ukraine’s needs through nuclear energy, this issue is very difficult and even to a certain extent possible with gigantic funding for the construction of new NPP, but not advisable.

Wind is only effective as an energy source in areas with strong and steady winds. Our country has good wind capacity, focused mostly in the south on the Black and Azov coasts and in the Carpathian and Crimean mountains. An analysis of long-term observations of weather stations indicates that in Ukraine wind flows prevail with average annual wind speeds of 5 m/sec, which is economically feasible for the development of this industry. In terms of the use of wind energy on land, the most favorable regions are the Crimea, the Carpathians, the coast of the Black and Azov seas (Odessa, Nikolaev, Kherson, Zaporizhzhya and Donetsk regions), and also Luhansk region. An important

factor to consider is the cost of wind power plants construction, which may reach $1-$4 million to install (depending on many factors) [51].

Solar is one of the territory's most popular renewables, but it is affected by changes in weather patterns changes in various seasons. The insolation of Ukraine, according to the available maps, is from 1150 to 1550 kW/m2 [40]. The maximum exposure is in the southern regions - Odessa, Kherson, Nikolaev. Ukraine's position contributes to solar projects; the insolation of our country is far higher than that of Germany– Europe's pioneer in solar power generation. However, the solar estimated potential (theoretical potential) significantly reduces when technical, economic, social and environmental factors and constraints for the deployment of solar energy systems are considered.

Wind and solar industries in the future, together will be able to occupy of the leading position in the production of environmentally friendly energy in Ukraine. There are many theories about how quickly the transition to renewable sources as wind energy will occur and to what extent. The Fig. 3.9 below shows the capabilities of this wind and solar industries in Ukraine (based on different theories and perspectives).

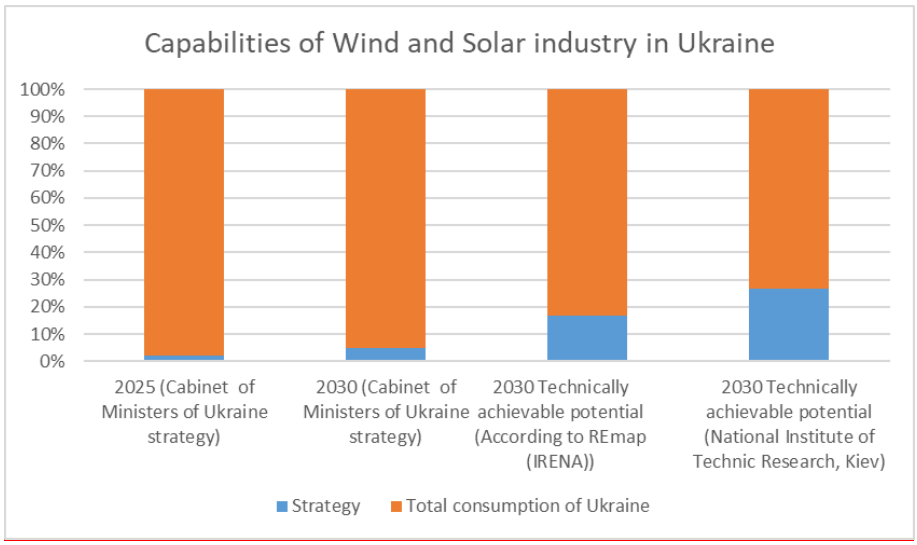


Fig. 3.9. Capabilities of Wind and Solar industry in Ukraine comparison [41, 44, 45]

Geothermal energy is characterized by geothermal gradient, which is less than 2°C/100 m (Carpathian mountain area), the highest geothermal gradients (up to 7-

8.4°C/100m) are observed in the Transcarpathian basin, the central part of the Crimean Peninsula, on the coast and the Black Sea [50].

According to Strategy of Ukraine for the period up to 2035 “Security, Energy Efficiency, Competitiveness” on 2015 Ukraine produced 0,5 Mtoe of geothermal energy, which amounted to 0,5% of the country's total consumption. According to the strategy of the Cabinet of Ministers of Ukraine for 2035, this figure will not increase too much and amount to 4 Mtoe, according to more optimistic forecasts and realizing the maximum potential of Ukraine, this figure may increase to 8.4 -12 Mtoe. Based on the data presented above, the graph below (Fig. 3.10) shows the theoretical possibilities for the development of geothermal energy and, on what share Ukraine will be able to satisfy its total needs (based on data on total consumption for 2018 [5].

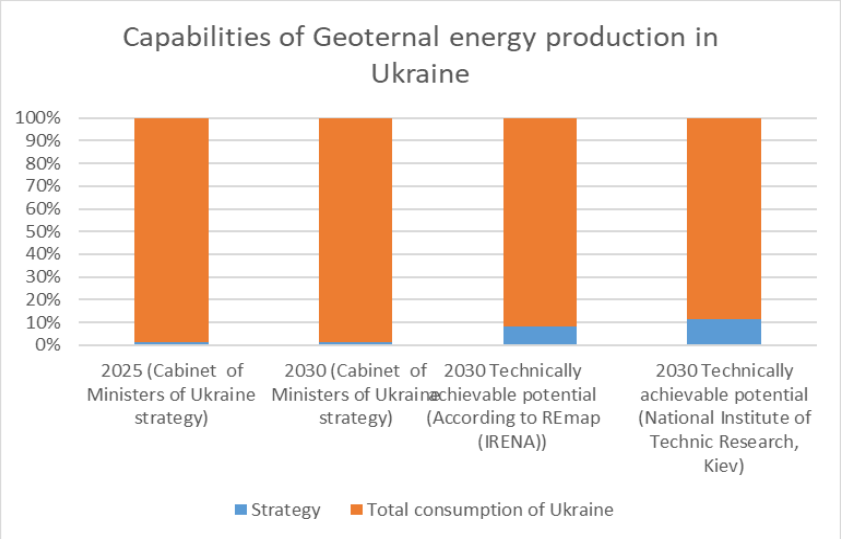


Fig. 3.10. Capabilities of geothermal energy production in Ukraine based on national and other strategies [41, 44, 45]

Unlike wind, solar and other renewable energy sources, *biomass* can have a beneficial effect on our environment by lessening our reliance on fossil fuels that cause climate change. Ukraine has great potential for biomass available for energy production, which is a good prerequisite for the dynamic development of the bioenergy sector. 110-120 million tons of biomass feedstock are generated annually in Ukraine (cereal trawl and other crop waste, animal and agro-industrial waste). Of the total amount, about 54 per cent is further processed, 45 percent is wasted and only about 1 percent is used for the

production of electricity and heat [47]. Geography potential of biomass energy in Ukraine characterized by specific waste resource:

• The Ukrainian's northern and western regions have extensive and dense vegetation including coniferous and deciduous forests.

• Numerous agro-industrial sites and vast agricultural areas are characteristic of the central and Southern parts.

• Large amounts of secondary biomass generates in the eastern part of the country by well-developed industrial and agro-industrial sectors.

For Ukraine, bioenergy is one of the strategic directions of development of the renewable energy sector and the first steps already been taken. In our country, there are already 5 power plants operating on solid bimass and 5 working on biogas of agricultural origin [48]. According to the data of "World energy Balances" for 2018, Ukraine produced 3.348 Mtoe of biofuel/waste energy, which amounted to 3,5% of the country's total consumption [5]. Different outlooks for the industry shown below (Fig. 3.11).

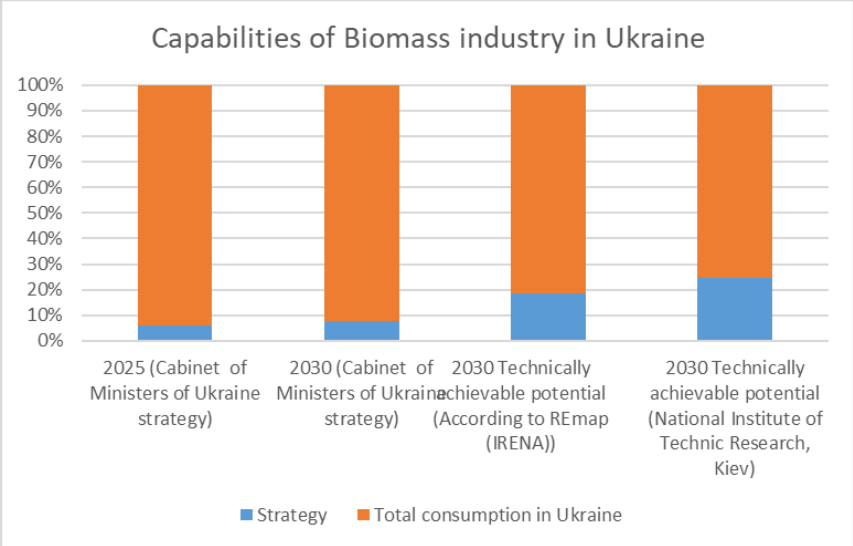


Fig. 3.11. Capabilities of biomass industry in Ukraine [41, 44, 45]

Energy mix: Of course, Ukraine can't satisfy its energy needs due to only "one" source, but due to the combination of all possible alternatives, its can work out. The transition from a fossil-fuel-based energy system to a RES-based system is a process in which medium-term, specific targets must guide the RES penetration – on this principle built the subsequent strategy. According to the strategy of the Cabinet of Ministers of

Ukraine, which provides the most easily feasible forecast, our country will be able to cover only 10.5% of its needs by 2025 and 16% by 2030, due to renewable energy mix (Fig. 3.12).

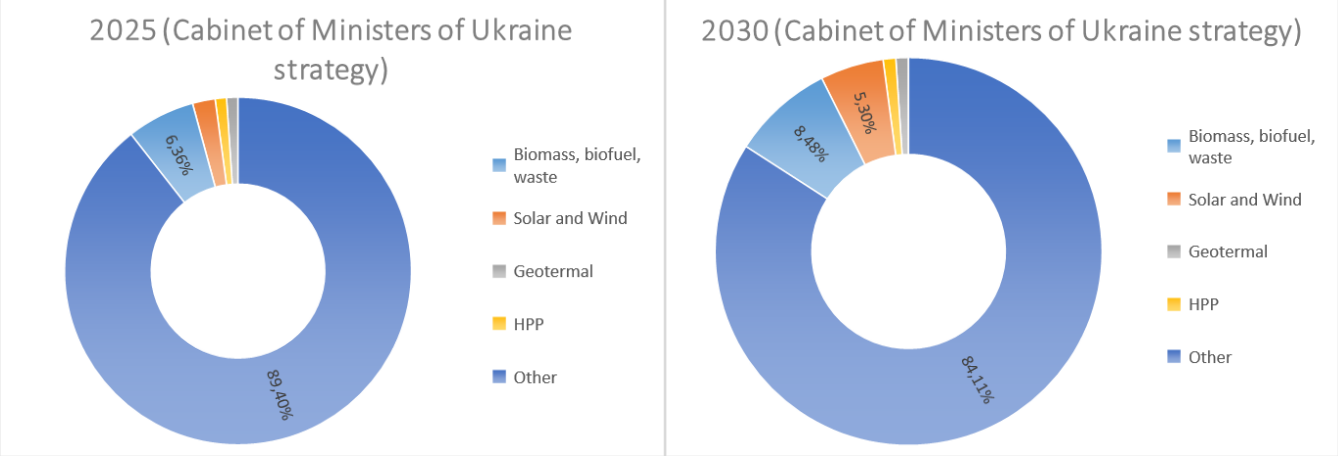


Fig. 3.12. Energy mix strategy for 2025 and 2030 [41]

The more ambitious goals set by the authors of the following outlooks and represent the maximum possible scenario using the entire available potential of Ukraine. According to REMAP "Renewable Energy Prospects for Ukraine", the maximal renewable energy production will reach 60%; National Institute of Technical Research expect greater value – 85% (Fig. 3.13).

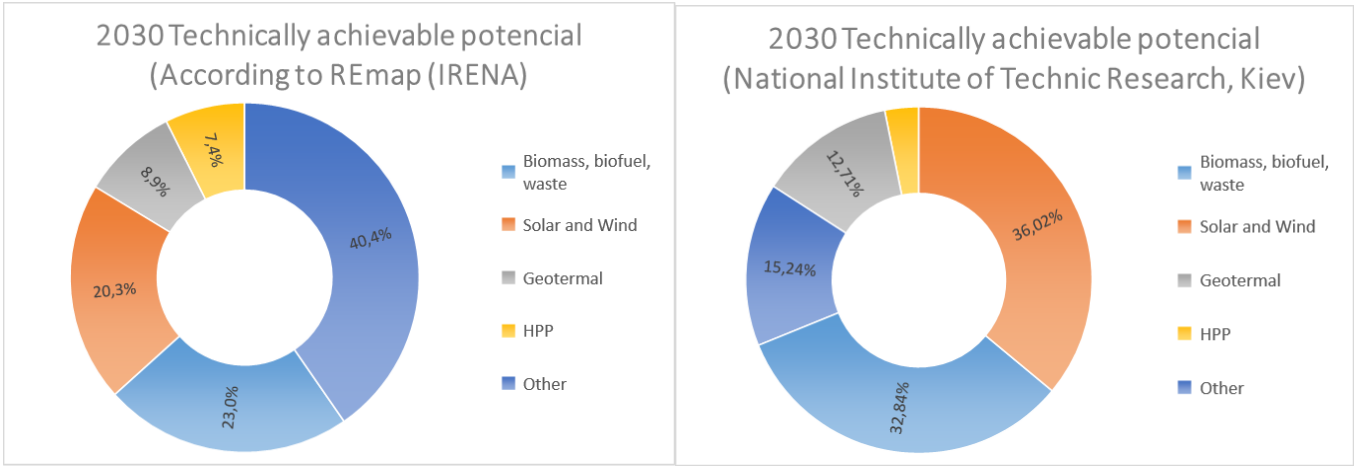


Fig. 3.13. Technically achievable potential in potential replacement of fossil fuels by renewables by 2030 [44, 45]

In the best-case scenario, our country will be able to meet its energy needs through renewable sources and the current level of nuclear energy production. Less favorable outlook will allow Ukraine to partially abandon fossil fuels and abandon energy import, and is a great step towards energy independence.

The appropriateness of using a particular energy sources depends not only on the amount of received energy, but also on the ecological, social and economic components. In order to assess the spectrum of advantages and disadvantages of the proposed options the following efficiency criteria were chosen:

- The degree of achieving overall objective of the project – the provision of the state energy needs;
- The economic efficiency of the project – the necessary state investments;
- The social concerns in the country – the effects on labor market, living standards, cost of living, etc.;
- The environmental negative impacts in the country;
- The environmental positive impacts in the country;
- The human health threats for the population of the country;
- The technical feasibility – in terms of available technologies and room for infrastructure development, suitable natural conditions, etc.

After comparing all the possible options, we can confidently say that the most acceptable strategy is energy mix, since none of the single alternatives if able to cover all the country needs in energy. The second ranks are taken by the solar and wind spheres. They are the most environmentally friendly, do not carry a risk to human health and can partially satisfy Ukrainian's energy needs. However, their combined potential for substitution is from 19 to 34%, which obviously not enough. Next are bioenergy, which is slightly less clean, and geothermal that shows good results, but is more difficult to implement and has some environmental impact. Nuclear energy showed the lowest score.

Table 3.4

Comparative analysis of substitution strategies for fossil fuels phase-out.

Alternative	Factors (sequence shown above)							Total
Nuclear	3	2	0	1	0	1	1	8
Wind	2	2	3	3	3	3	2	18
Solar	2	2	3	3	3	3	2	18
Geothermal	2	2	2	3	1	3	1	14
Bioenergy	2	2	2	3	2	2	2	15
Energy mix	3	2	3	3	3	3	2	19

If the country's renewable energy sector continues to grow, it will enhance energy security, market integration and decarbonisation. The path to "greening" Ukraine's energy market has both big challenges and opportunities. The path forward would be continuing energy market reforms, improving energy efficiency initiatives with emphasis on demand reduction, and increased investment in renewable energy to ensure energy stability.

The economic point of view is an essential part of the implementation and development of renewable energy. Ukraine's renewable energy capacity is not used to its fullest degree. Alternative power engineering is a priority area for development of the Ukrainian economy and a strong place for attracting foreign direct investment.

Conclusion for Chapter 3

In the third section of this thesis, the prospects of abandoning fossil fuels in Ukraine described and the current level of energy production and consumption was analyzed.

Most of the energy produced by Ukraine comes from fossil fuels (mainly coal and gas) and nuclear energy, but the problem is that our country cannot fully satisfy its energy needs through its own production.

It is difficult to give an accurate forecast of prospects, but we can consider several radically different strategies and based on them give own forecast of possibility of phase out fossil fuels in Ukraine. Outlooks that give the largest percentage of possible energy potential (60% and 80%) are also the most difficult to implement. According to more

realistic forecast (16% by 2030), it will not be able to fully cover our needs, but it will accelerate our energy independence. It is important not only how much energy we can receive from one or another source, but what economic, social and environmental benefits any option can give. These criteria examined in more detail and we can confidently assume that the wind and solar industries are the best alternatives for our country as single directions – but the most preferred option with the highest score is an energy mix that also includes a significant share of energy from these perfect sources.

CONCLUSIONS

1. World’s dependence on fossil fuels is one of the most important tests for humanity in the struggle for environment and at the same time for provision population with the necessary energy. Now less than 10% of the world’s energy is produced from renewable sources, the rest is based on fossil fuels and nuclear reactors. In Ukraine, the percentage of renewables is even lower, but according to research: “not everything is so bad” – our country has all opportunities for meeting its energy needs through alternative energy sources.

2. The first interest to renewable energy sources was initiated by the 70s energy crises. Now the major drivers for the demand on RES are the growing concerns about catastrophic environmental impacts of fossil fuels combustion. Renewable energy facilities typically have very low effects on the environment. Thus, many countries have already initiated the plans to abandon the fossil fuels in various sectors of industry, including decommissioning of coal power station and prohibition of cars with internat combustion engines. The corresponding programs of such type have been announced by Germany, France, Sweden, Denmark and other countries. Returning to renewables will help mitigate climate change and it is an excellent approach to meet future generations' energy demand.

3. Ukraine has been and remains the country dependent on external energy supplies and that is why our country needs to lift the share of renewable energy in the energy mix considerably. Thus, the reduction of the fossil fuels involvement in provision of industry and energy needs in Ukraine is driven by both political and environmental reasons. Clean technologies can also bring substantial indirect economic benefits, by creating new working places and improving living standards.

4. The World’s and Ukrainian experience reviewed and it is possible to make recommendations and own forecasts:

- After comparing all the possible options, we can confidently say that the most acceptable are the solar and wind spheres as single directions, but the most preferred

option with the highest score is an energy mix that also includes a significant share of energy from these perfect sources.;

- Although the development of nuclear energy can fully provide the country's energy needs, it can't be considered as an alternative through social and environmental factors. The country is unable to abandon it completely, and it's better to leave it at the current level;
- Until 2030, it is theoretically possible to increase the share of alternatives up to 60 – 80%, but gigantic investments needed and involve vast territories. And is unrealistic in current economic situation;
- The best decision of developing RES in Ukraine: adhere to the plan of the Cabinet of Ministers of Ukraine (10.5% by 2025 and 16% by 2030) and gradually increase its share in solar, wind, geothermal, hydro and bioenergy generation.

5. Energy security is the basis on which the future of the Ukrainian economy built and on which the quality and living standards of Ukrainians depend. If our country is able to use the maximum technical potential including solar, wind, hydro, bio and geothermal energy this will make it possible to gain energy independence. The development of only one renewable source will not produce the desired effect, but the combination of all possible including, to some extent, dangerous nuclear energy will make it possible to master such a necessary energy potential.

Ukraine is only at the beginning of the path to creating an efficient and balanced energy market, but we have all the prospects. It is important to remember that achieving energy independence and security is a powerful incentive to Ukrainian economic development.

REFERENCES

1. David JC MacKay Sustainable Energy — without the hot air. England, Cambridge: UIT Cambridge Ltd, 2009. 366 p.

2. Laura Cozzi Tim Gould World Energy Outlook 2018. International Energy Agency, 2018. 646 p.

3. G. Tyler Miller, Jr., Scott E. Spoolman Sustaining the Earth. USA, Belmont, CA: Brooks/Cole, 2009. 385 p.

4. Hal Marcovitz Can renewable energy replace fossil fuels?. USA, San Diego, CA: ReferencePoint Press, Inc., 2011. 96 p.

5. Statistics: World Energy Balances. International Energy Agency, 2018. 762 p.

6. The Keeling Curve URL: http://keelingcurve.ucsd.edu (Last accessed: 02.05.2020).

7. Krzysztof Mudryk, Sebastian Werle Renewable Energy Sources: Engineering, Technology, Innovation. Switzerland, Cham: Springer, 2018. 823 p.

8. Abbas Ghassemi Wind Energy: Renewable Energy and the Environment. USA, Boca Raton, FL: CRC Press, 2019. 305 p.

9. Vaughn Nelson Introduction to Renewable Energy. USA, Boca Raton, FL: CRC Press, 2011. 349 p.

10. Peter E. Hodgson Energy, the Environment and Climate Change. England, London: Imperial College Press, 2010. 220 p.

11. Peter Newman, Timothy Beatley, Heather Boyer Resilient Cities: Overcoming Fossil Fuel Dependence. USA, Washington: Island Press, 2017. 239 p.

12. Hermann Scheer Energy Autonomy: the economic, social and technological case for renewable energy. United Kingdom, London: Taylor and Francis Ltd, 2006. 320p.

13. Robert Curley Energy: Past, Present and Future - Fossil Fuels. USA, New York, NY: Britannica Educational Publishing, 2012. 142 p.

14. Robert Ehrlich, Harold A. Geller Renewable Energy, Second Edition. USA, Boca Raton: CRC Press, 2018. 485 p.

15. World Energy Outlook 2011. International Energy Agency, 2011. 664 p.

16. Vaclav Smil Energy at the crossroads: global perspectives and uncertainties. London, England: The MIT Press, 2003. 419 p.

17. V. Snihur, D. Malashkevych, T. Vvedenska Tendencies of Coal Industry Development in Ukraine. Ukraine, Dnipro: Dnipro University of Technology Underground Mining Department, 2016. 8 p.

18. The Role and Place of Ukraine's Energy Sector in Global Energy Processes. Ukraine, Kiev: Razumkov Centre, 2018. 80 p.

19. Ukraine Country Profile. Ukraine, Kiev: American Chamber of Commerce in Ukraine, 2019. 122 p.

20. Dmytro Chumak, Andrian Prokip European View: Regional stability through energy cooperation: The case of the EU and Ukraine. Ukraine: SAGE journals, 2018. 8 p.

21. BP Statistical Review of World Energy 2018 67th edition. England, London: BP p.l.c., 2018. 56 p.

22. BP Statistical Review of World Energy 2019 68th edition. England, London: BP p.l.c., 2019. 64 p.

23. Jan Burck, Ursula Hagen, Franziska Marten, Niklas Höhne, Christoph Bals NewClimate Institute & Climate Action Network: Results 2019. Germanwatch, 2019. 22 p.

24. Alexander Zvorykin, Igor Pioro, Raj Panchal Study on Current Status and Future Development in Nuclear-Power Industry of Ukraine. USA, Charlotte, North Carolina: 24th International Conference on Nuclear Engineering, 2016. 10 p.

25. Oleksandr Diachuk, Maksym Chepeliev, Roman Podolets, and other Transition of Ukraine to the Renewable Energy by 2050. Ukraine, Kiev: Heinrich Boell Foundation Regional Office in Ukraine, State Organization "Institute for Economics and Forecasting" of the National Academy of Sciences of Ukraine, 2017. 90 p.

26. Ukrainian Energy Market: Overview of the sector and future projects. Belgium, Brussels: Flanders: State of the Art, 2018. 56 p.

27. Eugene D. Coyle, Richard A. Simmons Understanding the Global Energy Crisis. USA, West Lafayette, Indiana: Purdue University Press, 2014. 291 p.

28. Pierre Gadonneix, Marie-José Nadeau, Younghoon David Kim and other World Energy Resources: Peat. United Kingdom, London: World Energy Council, 2013. 468 p.

29. World Energy Resources 2016. United Kingdom, London: World Energy Council, 2016. 1028 p.

30. Per Capita Electricity Consumption 2014. URL: https://ourworldindata.org/grapher/electricity-per-capita (Last accessed: 02.05.2020).

31. Tibi Puiu How long before the world runs out of fossil fuels?. URL: https://www.zmescience.com/other/feature-post/how-long-fossil-fuels-last-43432/ (Last accessed: 04.05.2020)

32. Hannah Ritchie, Max Roser Fossil Fuels. URL: https://ourworldindata.org/fossil-fuels (Last Accessed: 08.05.2020)

33. Investments In Renewable Energy by Technology. URL: https://ourworldindata.org/grapher/investment-in-renewable-energy-by-technology (Last Accessed: 13.05.2020)

34. World Nuclear Association: Nuclear Power in Ukraine. URL: https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/ukraine.aspx (Last Accessed 15.05.2020)

35. Wojciech Konończuk Gas revolution? Prospects for increasing gas production in Ukraine. URL: https://energypost.eu/increasing-production-of-gas-in-ukraine/ (Last Accessed 15.05.2020)

36. Irina Golod The head of "Nadra of Ukraine": "Ukraine has enough hydrocarbon reserves for 140 years". URL: https://www.google.com.ua/amp/s/daily.rbc.ua/rus/show/glava-nadra-ukrainy-ukrainesvoih-zapasov-uglevodorodov-02122014122400/amp (Last Accessed 15.05.2020)

37. Coal bed methane in Ukraine. URL: http://shalegas.in.ua/en/metan-vugil-nyh-plastiv-v-ukrayini/ (Last Accessed 18.05.2020)

38. Phase-out of fossil fuel vehicles. URL: https://en.m.wikipedia.org/wiki/Phase-out_of_fossil_fuel_vehicles (Last Accessed 18.05.2020)

39. Fossil fuel phase-out. URL: https://en.m.wikipedia.org/wiki/Fossil_fuel_phase-out (Last Accessed 18.05.2020)

40. Solar Insolation: Ukraine's Potential. URL: https://karbon-cns.com.ua/solnechnaya-insolyaciya.html (Last Accessed 19.05.2020)

41. Approved by Resolution of the Cabinet of Ministers of Ukraine of 18 August, 2017 No. 605-p Energy Strategy of Ukraine for the Period up to 2035 “Security , Energy Efficiency, Competitiveness”. Ukraine, Kiev: 2017. 31 p.

42. Yuliya Kovaliv Renewable energy sector: Unlocking sustainable energy potential. Ukraine: National Investment Council, 2018. 32 p.

43. A. N. Limarenko Potential and need for development of non- traditional renewable energy resources in Ukraine. Ukraine, Poltava: Poltava: East European Journal of Advanced Technology, 2012. 6 p.

44. IRENA: REmap 2030 Renewable Energy Prospects for Ukraine. Germany, Bonn: International Renewable Energy Agency, 2015. 47 p.

45. O. M. Sukhodolya, A. Yu., Smenkovsky; A. I. Shevtsov, M. G. Zemlianiy Status and prospects of renewable energy development in Ukraine. Ukraine, Kiev: National Institute for Strategic Studies, 2014. 104 p.

46. Operating NPP. URL: https://www.uatom.org/zagalni-vidomosti (Last Accessed 10.05.2020)

47. Bioenergy & Biobased Opportunities in Ukraine. Ukraine: Ministry of Economic Affaires, 2013. 77 p.

48. Bioenergy market in Ukraine: prospects and obstacles. URL: http://www.biowatt.com.ua/analitika/rynok-bioenergetiki-v-ukraine-perspektivy-i-prepyatstviya/ (Last Accessed: 20.05.2020)

49. T. Kurbatova, H. Khlyap State and economic prospects of developing potential of non-renewable and renewable energy resources in Ukraine. URL: https://www.sciencedirect.com/science/article/abs/pii/S1364032115007406 (Last Accessed 20.05.2020)

50. Yurii Morozov, Anastasia Barylo Geothermal Energy Use, Country Update for Ukraine. Ukraine, Kiev: European Geothermal Congress, 2019. 6 p.

51. How much do wind turbines cost? URL: http://www.windustry.org/how_much_do_wind_turbines_cost (Last Accessed: 25.05.2020)

52. Paul Hawken The most comprehensive plan ever proposed to reverse global warming. USA, New York: Penguin Books, 2017. 468 p.

53. Lester R. Brown The great transition: Shifting from fossil fuels to solar and wind energy. England, London: W.W. Norton & Company, 2015. 257 p.

54. Coal URL: https://wikimili.com/en/Coal) (Last Accessed: 20.05.2020)

55. Peat URL: https://en.wikipedia.org/wiki/Peat (Last Accessed: 21.05.2020)

56. Alex Apstein The Moral Case of Fossil Fuels. USA, New York: Penguin Group, 2014. 190 p.

57. History of oil and gas extraction in Ukraine URL: https://biz.nv.ua/naftogaz-vs-gazprom/ukraine-s-oil-and-gas-industry-has-a-long-and-interesting-history-50011448.html (Last Accessed: 23.05.2020)