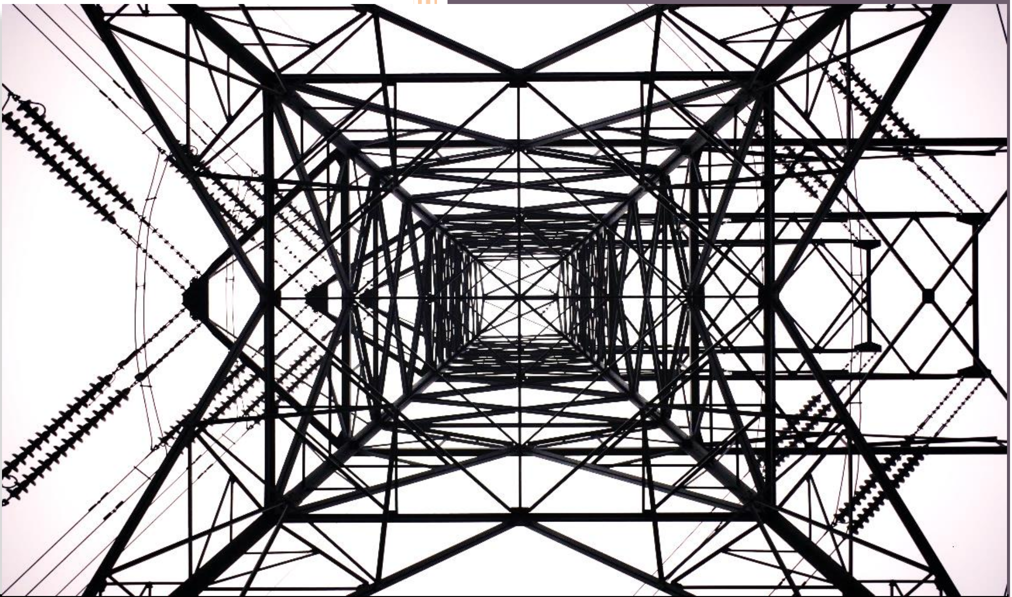

EUROPEAN ENERGY COLLABORATION: MODERN SMART SPECIALIZATION STRATEGIES

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MONOGRAPH

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European Energy Collaboration: Modern Smart Specialization Strategies

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CONTENT

INTRODUCTION

Given the importance of energy cooperation and collaboration in Europe, possibilities to provide the infrastructure development and to establish the necessary interconnections between energy resource operators, to manage energy flows and communication among Pan-European energy market agents, to apply innovative technologies to achieve the benefits in smart specialization strategies are highlighted.

The existing energy systems are insufficiently equipped to meet the users' newest needs by such parameters as energy efficiency, reliability, cost-effectiveness, responsibility for the environment. Taking these parameters into account, one can find the future specialization vector of countries in the energy sphere. The deployment of smart energy grids is indispensable for improving energy efficiency, stimulating economic development and growth. In this regard, the formation of the European Union's energy policy is aimed at increasing security of energy supply and improving the renewable energy use through various incentive measures provided by the strategies and directives of EU Member States.

Nowadays, developed countries are transforming their national strategies to expand renewable energy sources in energy consumption across all sectors of the economy. Energy policies, together with energy security policies, are formed to take into account the emerging needs of energy infrastructure development. Not all European countries have sufficient reserves of conventional energy sources, so there is a need to import resources. Given the controversy that arises between countries over energy transportation, economic and political interference, European countries are looking for sustainable energy sources to diversify their energy supply. Thus, energy security is achieved by expanding the consumption of renewable energy generated from internal or external energy sources.

That is why the priority task is to introduce and to implement smart technologies in the energy sector, proper cooperation and collaboration for a strategic restructuring of the energy market. In this direction, more and more attention is paid to the development of smart grids as a basis for the future development of the energy sector. However, it should be noted that smart grid technologies implementation is a rather complex process that requires deep studies and analysis.

Thus, the first chapter of the monograph analyzes the global balance in the electricity market, identifies the negative effects of energy production, and defines the clean energy concept. The second chapter includes materials on strategic perspectives to use renewable energy sources and investments in renewable energy.

The third chapter investigates the prerequisites for energy cooperation in Europe, the infrastructural aspect of the smart energy networks deployment, and the ways in which the state supports innovative transformations in the energy security field.

The description of issues regarding energy security and the development of smart grid technologies, preconditions for energy security in the context of climate change issues and the institutional components of energy security in EU countries is presented in the fourth chapter.

The exploring of the features of smart grid project formation in the context of the smart city international consortiums implementation, the experience to implement smart grid projects is provided in the fifth chapter. The sixth chapter concludes the monograph by exploring the the dissemination of energy-efficient innovative technologies.

The monograph was performed within the framework of the research theme “*The Optimization Model of Smart and Secure Energy Grids Building: an Innovative Technologies of Enterprises and Regions Ecologisation*” (state registration number 0119U100766), which is financed by the State budget of Ukraine and was prepared by authors:

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– *Liudmyla Saher* (chapter 6).

CHAPTER 1 PRECONDITIONS OF THE TRANSITION TO THE CLEAN ENERGY CONCEPT

1.1 Global balance in the electricity market

In recent decades, due to the global environmental, energy and economic crises, the development level of the fuel and energy complex has become one of the dominant factors which define the national security level, the country's competitiveness in the world market and its economic stability.

The world electricity development began in 1891 when the first attempt to transmit electricity to a distance was made. Steam engines have replaced heat engines; some technologies used to produce energy products have displaced others due to unmet needs and requirements of scientific and technological progress, the question of increasing the power plants capacity arose (Meadows, 1994). In response to the growing social needs to increase electricity consumption, its production technologies were changed to more powerful ones, which could provide uninterrupted electricity supply.

The level of access to the power supply in the modern world is measured by the production electrification index (in 2009 it was 80%, it means that 20% of the world's population did not have access to electricity (Kozmenko et al., 2005)). The levels of electrification (percentage of the country’s population with access to electricity) by the world’s region in 2013 are presented in Table 1.

TABLE 1. LEVELS OF THE ELECTRIFICATION BY THE WORLD'S REGIONS IN 2013

Region	Population with no access to electricity, millions	Level of the electrification , %	Level of electrification in cities, %	Level of electrification in villages, %
The countries of North Africa	2.0	99.0	99.6	98.4
The countries of South Africa	585.0	30.5	59.9	14.2
Developing Asian countries	675.0	81.0	94.0	73.2
China and the countries of East Asia	182.0	90.8	96.4	86.4
South Asian countries	483.0	68.5	89.5	59.9
Latin American countries	31.0	93.2	98.8	73.6
Middle East countries	21.0	89.0	98.5	71.8
Developing countries of the world	1.3	74.4	90.6	63.2
Countries, Members of the Economic Co-operation and Development Organization.and Eastern Europe (Asia)	1.3	80.5	93.7	68.0

Source: data from (NKRE, 2013)

Electricity can be produced at different power plants (thermal power plants, nuclear power plants, wind power plants, power plants which work on biomass, biogas, biofuels, etc.) that use different energy resources (natural gas, coal, wind energy, geothermal energy, etc.). The volumes of electricity generation by different technologies of its producing in different countries of the world in 2012 are shown in Table 2.

TABLE 2. ELECTRICITY PRODUCTION VOLUME BY DIFFERENT TECHNOLOGIES IN DIFFERENT COUNTRIES OF THE WORLD IN 2012, TWH.

Country	Energy resource						
	Nuclear fuel	Energy of water	Energy of soil	Solar, wind energy	Fossil fuel	Biofuels and wastes	Total
France	428.52	66.83	n/a	11.06	55.89	6.80	569.10
Germany	140.56	27.36	0.03	52.44	368.74	39.87	628.98
Italy	n/a	54.41	5.38	11.81	218.89	11.59	302.06
Japan	288,23	90.68	2.63	7.76	706.46	23.45	1119.22
Poland	n/a	3.49	n/a	1.66	145.96	6.55	157.66
Slovenia	5.66	4.70	n/a	0.01	5.84	0.22	16.43
Spain	61.99	45.49	n/a	51.44	139.50	4.68	303.09
United Kingdom	62.14	6.75	n/a	10.22	288.66	13.36	381.13
USA	838.93	286.33	17.58	100.00	3060.15	75.43	4378.42
Republic of Belarus	n/a	0.05	n/a	0.00	34.64	0.21	34.90
Ukraine	89.15	13.15	n/a	0.10	85.90	0.28	188.58

Source: data from (IEA, 2012)
Note: n/a – no data available

The world balance of electricity production, export and import as of 2012 is presented in Fig. 1. The largest producers of electricity are thermal power plants that use fossil fuels (coal, gas, oil, etc.) as energy sources. These fuels provide 80% of the world's energy demand annually (IEA, 2014). For example, as of 2012, 29% of world electricity was generated from coal and 31% from oil. Coal production had a tendency to increase every year (in 2012 it increased by only 0.4%, which means that the transition process to electricity production from non-fossil fuels was intensified). The largest coal reserves are located in Indonesia, Australia, Russia, South Africa, Colombia and the United States (IEA, n.a.).

Over the last decade, demand for natural gas has increased by 800 billion m3 compared to the previous period. About 3,500 billion m3 of natural gas is consumed each year. The world's largest consumers of this type of energy are the Russian Federation, the United States of America, Canada, Qatar and Iran. Electricity consumes 40% of the world's natural gas production as energy. Information on the dynamics of the fossil fuels supply and consumption in the economically developed countries for 2011-2012 is presented in Table. 3.

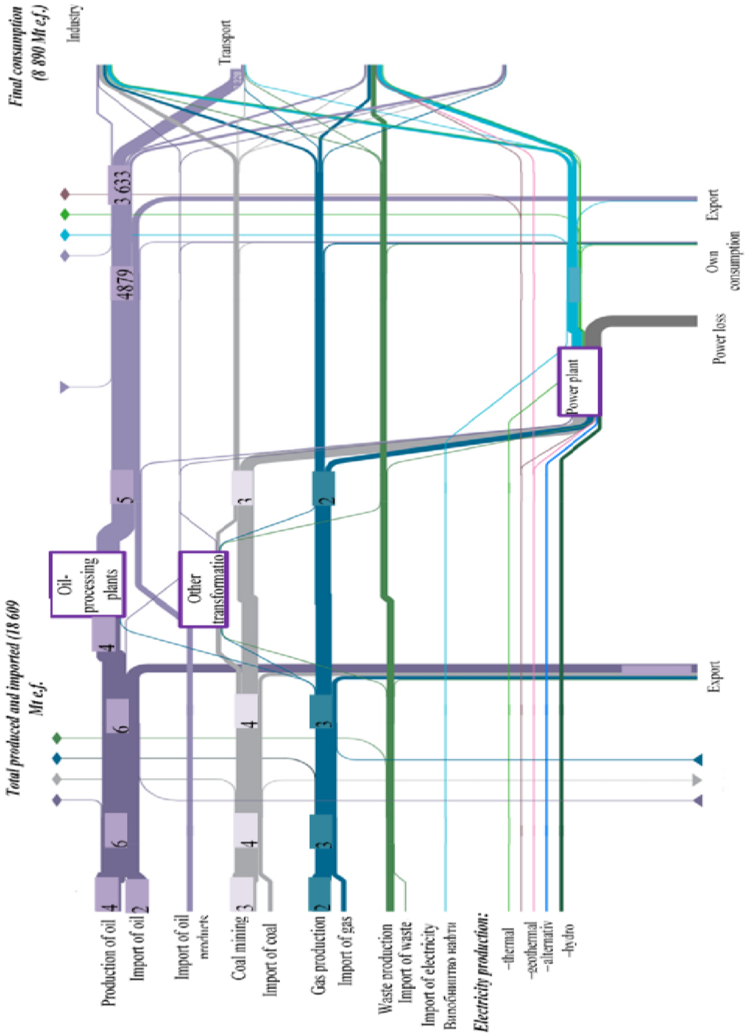

FIG. 1. THE WORLD BALANCE OF PRODUCTION, IMPORT AND EXPORT OF ELECTRICITY AS OF 2012

Source: data from (IEA, 2012)
Note: e.. f. – equivalent fuel (the heat of the fuel combustion is equal 29.3 MJ/kg, or 7 000 kcal/kg

TABLE 3. VOLUMES OF FOSSIL FUELS SUPPLY AND CONSUMPTION IN ECONOMICALLY DEVELOPED COUNTRIES FOR 2011-2012 (MILLION BARRELS)

	Fossil fuels			
	coal	Raw oil	Oil products	Natural gas
Dynamics of the fuel extraction	+952.55	+933.13	n/a*	+1 006.80
Dynamics of fuel import volumes	+387.11	+1 483.56	+565.42	+650.40
Dynamics of fuel export volumes	–319.42	–348.40	–566.58	–316.50
Dynamics of fuel transportation volumes in bunkers by sea	n/a*	n/a*	–75.68	n/a*
Dynamics of fuel transportation volumes in bunkers by air	n/a*	n/a*	–87.09	n/a*
Dynamics of fuel stocks	–0.38	–5.56	+2.38	+4.32
Dynamics of fuel consumption by power plants	–727.20	–11.67	–61.68	–383.80
Dynamics of fuel consumption by heating plants	–77.81	n/a*	–13.10	–114.46
Dynamics of fuel consumption by thermal power plants	–5.07	n/a*	–1.19	–8.22

Source: data from (IEA, 2014)
Note: «+» – increase in volumes in 2012. In comparison with 2011; «–» – decrease in volumes in 2012 in comparison with 2011; n/a – no data available

Global energy consumption in 2012 increased by 0.9% compared to its global consumption in 1990, with an average growth rate of 2.1%. China has played a significant role in such dynamics, where energy consumption growth compared to 1998 was only 2.6% at the same level of electricity consumption (Finance.ua, 2014).

1.2 Negative consequences of the energy resources production

The sustainable development of the energy sector means a balance in the development of three interconnected components: economic feasibility, impact on the environment and social consequences (Burkynskyy et al., 2012). There are cause-effect relations between these groups when a breach of the first group causes a breach of the second one, and the sustainability of the third group is a consequence of the progress of the second one. The relationship of the components proves the sustainability of the system as a whole: making efforts only to develop the industry from an economic point of view without taking into account the environmental one, will result in a deterioration of the environment, rendering the living conditions and human life unusable.

There are direct and remote negative social consequences of power plants operation. The direct negative social consequences are determined by the number of deaths during the extraction, treatment, transportation and use of energy fuels, operation of power plants and remote consequences are defined by the slow cumulative effect (burning of energy resources, epidemics after flooding) on the health of the population. The positive and negative consequences of energy development in accordance with the basic components of the sustainable development concept are given in Table. 4.

TABLE 4. NEGATIVE SOCIAL CONSEQUENCES OF POWER PLANTS OPERATION WHICH WORK ON DIFFERENT KINDS OF ENERGY RESOURCES

Energy resource	Number of deaths related to the production of 1 GWh of electricity			
	Among workers of the energy sector		Among inhabitants	
	Direct impact	Remote impact	Direct impact	Remote impact
Coal	0.16 – 3.2	0.02 – 1.1	0.1 – 1.0	2.0 – 6.0
Oil	0.2 – 1.35	n/a	0.01 – 0.1	2.0 – 6.0
Natural gas	0.1 – 1.0	n/a	0.2	0.004 – 0.2
Nuclear fuel	0.07 – 0.5	0.07 – 0.37	0.001	0.005 – 0.2
Water energy	0.5 – 4	n/a	0.2	0.004 – 0.2
Solar, wind energy	0.007 – 0.5	n/a	0.05 – 2.0	0.05 – 2.0

Source: data from (Kozmenko et al., 2005)
Note: n/a – no data available

During the electricity generation at power plants operating on fossil energy sources, emissions of harmful substances get into the environment: gaseous emissions (nitrogen oxides, sulfur dioxide, solids, carbon oxides, carbon dioxide) and heavy metals emissions (lead, mercury, chromium, nickel, copper, zinc, arsenic). Particularly dangerous in this list are carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), and aerosol solids (PM2.5) with a diameter of 2.5 μm and less. Thus, in 2014, the amount of sulfur dioxide in the world was 86,716 thousand tons, nitrogen oxides - 77,357 thousand tons, solids of aerosols (PM2.5) - 41,076 thousand tons (Kozmenko et al., 2005).

Despite the diversity of pollutant emissions into the environment from power plants, today in the world, the level of environmental pollution is measured by the amount of carbon dioxide emissions that mainly feed into the atmosphere through the combustion of fossil fuels during electricity generation by thermal power plants. Carbon dioxide emissions are non-toxic (Hazizullin et al., 2011), but a significant amount of carbon dioxide entering the atmosphere causes weak environmental regeneration and poor air circulation.

Table 5 shows the amount of supplied electricity in different countries of the world and the amount of carbon dioxide during its production.

It is scientifically proved that the environmental impact, made by different types of power plants, is measured not only by direct emissions of CO2 into the atmosphere but also by emissions from the construction of energy facilities or waste management. For example, nuclear power plants harm the environment by dumping radioactive waste. The operation of hydropower plants leads to significant economic, environmental and social losses. For example, due to heavy rainfall, hydropower plants dams cannot withstand the increase of water resources in the upper beams of the station and breakthrough, which will flood the territory.

The most acute problem of our time is the problem of limiting and reducing carbon dioxide emissions into the environment. Every year, carbon dioxide emissions in the world tended to increase, and only in 2009, the number of harmful emissions into the atmosphere decreased slightly, which is explained by the decrease in production volumes due to the global economic crisis. The amounts of CO2 emissions by different types of power plants in different countries of the world in 2012 are given in Table. 6.

TABLE 5. VOLUMES OF THE SUPPLIED ELECTRICITY AND CO2 EMISSIONS IN DIFFERENT COUNTRIES OF THE WORLD AS FOR 2012

Country	The volume of the supplied electricity, TWh	CO_2 emissions during fuel combustion, mln. t	CO_2 emissions during the production of heat energy and electricity, mln. t	CO_2 emissions per population in the country, t /1 person	CO_2 emissions, kg per 1 UA dollar
France	556.90	5 103.00	328.30	5.10	0.17
Germany	602.40	9 220.00	747.60	9.22	0.26
Italy	300.60	6 153.00	393.30	6.15	0.23
Japan	1 042.70	9 591.00	1186.00	9.59	0.31
Poland	163.10	7 623.00	300.00	7.62	0.42
Slovenia	15.90	7 111.00	15.30	7.11	0.29
Spain	289.00	5 775.00	270.30	5.77	0.22
United Kingdom	364.90	7 181.00	443.00	7.18	0.22
USA	4 326.60	16 145.00	5287.20	16.15	0.36
Belorussia	30.80	7 515.00	66.00	7.51	0.50
Russian Federation	1 069.30	11 559.00	1653.20	11.56	0.76
Ukraine	198.40	6 165.00	285.40	6.16	0.83

Source: data from (IEA, 2012)

TABLE 6. AMOUNTS OF CO_2 EMISSIONS BY DIFFERENT TYPES OF POWER PLANTS IN DIFFERENT COUNTRIES OF THE WORLD IN 2012, MLN T

Country	Thermal power plants, which work on		
	gas	Coal	oil
France	85.3	40.2	202.6
Germany	163.1	317.5	256.7
Italy	142.0	60.4	167.4
Japan	259.8	419.7	535.8
Poland	29.2	198.7	63.0
Slovenia	1.7	5.7	7.1
Spain	65.2	58.4	142.2
United Kingdom	152.5	143.5	157.9
USA	1 375.0	1 612.8	2 055.5
Belorussia	38.3	3.0	29.7
Russian Federation	864.9	425.2	350.0
Ukraine	95.1	149.6	36.4

Source: data from (IEA, 2012)

In 2012, CO_2 emissions from fossil fuel combustion reached a catastrophic level - an increase of 3.16 Gt in 1 year (in 2011 - 1 Gt), which leads to climate change, accompanied by an increase in global temperature on Earth by 80% (IEA, 2011; IEA, 2012). It is possible to halt the global warming process and to reduce greenhouse gas emissions by 1) switching to the generation of electricity from alternative fuels or the use of carbon capture technologies; 2) reduction of electricity consumption through energy-saving technologies or the abandonment of certain goods (for example, cycling instead of using a car). If greenhouse gas emissions are not reduced, then CO_2 emissions will be doubled, leading to a demand increase for electricity and energy resources and, consequently, to an increased risk of energy supply (IEA, 2010).

In general, any method of electricity production is more or less related to a certain negative impact on the environment. Thus, the main environmental and economic problems of the hydropower plants' operation include: flooding of large areas of land during water intake into the upper basins; reforming the banks of reservoirs and springs in the lower beef; relocation of people to create a reservoir; change of hydrological and hydraulic regimes in the reservoir zone, which leads to deterioration of conditions for natural self-purification processes and natural quality formation of water resources; blocking of fish migration routes; deterioration of sanitary and hygienic conditions during intensive development of algae ("flowering of water"); change of microclimate, infrastructure, living conditions etc.

Significant disproportions of power plants' capacity allocation, a small share of the environmental, recreational, historical and cultural purpose territories are caused by excessive technogenic load on the environment and a high degree of pollution.

Carbon dioxide emissions from gas-fired power plants are lower than those from coal-fired or oil-fired power plants. Experts from the International Energy Agency have suggested that, if one uses only natural gas as a fossil energy fuel and introduces carbon capture and storage technologies, carbon dioxide emissions from thermal power plants will be reduced by adding biomass to fossil fuels (IEA, n.a.). This comprehensive utilization of the resource at a ratio of 5: 95 will reduce CO_2 emissions by 300 Mt per 1 year. In this case, the integrated use of fuels is almost twice as effective as the operation of biomass-only power plants (Naumenko, 1996).

Scientists of the International Atomic Agency have proved that environmental pollution occurred not only during direct production of electricity by energy resources combustion but also during the preparatory (coal extraction) or utilization (radioactive waste disposal) work. Thus, during the extraction and enrichment of uranium, CO2 emissions are generated and released into the environment. Hydropower plants generate methane at the bottom of reservoirs as a result of the decomposition of organic matter, which then enters the environment as carbon dioxide.

In 1970, during the energy crisis, the transition from using fossil fuels to practically inexhaustible or renewable energy sources to reduce carbon dioxide emissions into the atmosphere became relevant. At that time, special hopes were placed on nuclear power using multiplier reactors.

In the 1980s and 1990s, the energy crisis changed into an environmental one, so special attention was paid to solving the environmental problems related to energy. At the same time, it requires considerable financial, labour and material resources, so for many centuries, humanity continues to combust cheap organic fuel, to increase the amount of environmental damage, and incur additional costs to eliminate environmental problems.

If in the '50s of the twentieth century the transition to new technologies for the production of energy products was driven by needs to deploy capacities; today, it happens in order to minimize the environmental burden. Previously, only the capital and current costs for power plant's operating were included in the economic calculations, but today these calculations also include environmental costs, both preventive and compensatory.

1.3 The clean energy concept

The sustainable development concept was first introduced in the Central and Eastern Europe countries, and today it is widely implemented around the world. It is focused on the comprehensive solutions to the problems of economic feasibility, impact on the environment and social consequences, as well as the formation of a fundamentally new system of mechanisms for greening any production.

According to the basic principles of the human sustainable development doctrine, as well as taking into account the energy crisis consequences, the relevance to introduce the clean energy concept is increased. It provides the introduction of integrated clean energy systems, the optimum combination of organic and nuclear fuels, the transition to inexhaustible energy sources and synthetic energy, the implementation of clean technologies of energy production and use. Its main purpose is to meet the requirements of the Sustainable Development Concept adopted in 1992 at the United Nations Conference in Rio de Janeiro, namely: to reduce harmful emissions, reduce the accumulation of harmful substances in the environment, and to conserve and restore natural resource potential of separate territories and the planet as a whole (NKPE, 2013).

Clean energy is a change in the strategic vector of energy development in the direction of reducing the fossil fuels use, production and consumption of electricity at the expense of energy-efficient and resource-saving technologies (IEA, 2012).

The transition of Ukraine to the concept of clean energy is accompanied by a number of problems, most of which are financial ones (investments in new technologies) or caused by the social disinterest of the population.

The most important step in the transition to clean energy is to use alternative energy sources (Halushkina et al., 2013).

Nuclear power is considered to be the safest in the environment in terms of greenhouse gas emissions. Despite the large-scale consequences of the accidents (at the Chornobyl Nuclear Power Plant, at the Fukushima Nuclear Power Plant, etc.), scientists have shown that the prospects for nuclear power remain positive in the short and long term. In order for the average annual global temperature not to rise in 2020, it is necessary to increase the nuclear power share by 17% in the electricity structure with constant electricity production. For example, China plans to increase its share of nuclear power to 58 GW by 2020 compared to 17 GW in 2014 (ORLEN, 2014).

Scientists from the International Energy Agency have developed a prediction for the dynamics of increasing the alternative energy capacity in the world by 2020 (Table 7).

The leading countries in the introduction of alternative energy are Germany (36% of total electricity production), Spain (13%), Italy (13%), United Kingdom (8%), France (7%), Switzerland (3%).

Much attention is also paid to green energy in the world, which involves the production of electricity from inexhaustible sources. In 2012, the share of electricity generation from renewable energy sources was 13.2%, and in 2013 this figure was 22%. The increase in the share of alternative energy sources contributes to the diversification of suppliers, which increases the level of energy security of the country (IEA, n.a.).

Scientists from the International Energy Agency have developed a prediction for the dynamics to increase the capacity of alternative energy in the world by 2020 (Table 7).

TABLE 7. PREDICTION OF THE ELECTRICITY PRODUCTION AMOUNTS OWING TO THE ALTERNATIVE ENERGY DEVELOPMENT BY 2020 (GW)

Energy type	Year							
	2013	2014	2015	2016	2017	2018	2019	2020
Hydropower	1133	1168	1203	1237	1270	1307	1333	1360
Bioenergy	88	93	97	104	111	118	125	133
Wind energy	319	363	407	449	491	536	583	630
Solar energy	137	176	214	253	289	326	364	403
Geothermal power	12	12	13	13	14	15	15	16
Ocean Energy	1	1	1	1	1	1	1	1

Source: data from (IEA, 2013)

The first steps towards the transition to clean energy were the creation of the Congress of Ministries of States in 2010 that agreed to implement the Clean Energy Ministerial. It has brought together 22 countries (these countries account for 75% of world electricity consumption, 80% of global CO2 emissions and 75% of world GDP (IEA, 2013)).

The main scenarios for the development of world electricity investigated by this congress are the following:

1) a "new order" scenario, which involves the phasing out of fossil fuels to comply with political commitments regarding greenhouse gas emissions reduction;

2) the "450" scenario, which provides the development of energy systems in accordance with the strategy of limiting global temperature rise by 2 0C by 2035, thereby reducing the concentration of greenhouse gases in the atmosphere by 450 parts per million of CO2 emissions;

3) an "efficient world" scenario, focused on potential energy savings through the introduction of energy-efficient technologies for its generation;

4) an access scenario that foresees additional investments to provide the society with energy by 2030.

The International Energy Agency has developed other several scenarios to develop global energy (6DS, 4DS and 2DS), which focus on halting the rapid rise in global temperature, reducing greenhouse gas emissions and the consumed electricity amount:

1) the 6DS scenario continues current trends in energy development, ie an increase in electricity consumption by almost twice by 2050 (compared to 2009), an increase in total greenhouse gas emissions, no attempts to reduce it, and an increase in global temperature by 6oC on average. 2035;

2) the 4DS scenario predicts a global temperature rise of 4oC by 2035 and is in line with the World Energy Perspective, which involves reducing greenhouse gas emissions into the environment and intensifying efforts to improve the efficiency of power plants. This energy development scenario requires significant changes in policy and technology, as well as a further significant reduction of CO2 emissions after 2050;

3) the 2DS scenario guarantees a reduction of harmful emissions into the environment, which by 80% makes it possible to increase the global temperature by 2oC by 2035 (European Comission, 2010).

The 2DS scenario is considered to be a clean energy development scenario that requires significant investment in the energy sector, namely: $ 6,500 billion in 2010-2020, $ 8,700 billion in 2020-2030, $ 20,700 billion in the period 2030-2050 (IEA, 2012).

In order to reduce the CO2level in the environment, it is necessary to take into account the relationship between the intensity of CO2 emissions from energy companies and the electricity consumption volume. The solution to the decarbonisation (carbon loss) of the energy sector depends in part on the intensity of CO_2 emissions (ESCII indicator): global energy consumption must be reduced and energy, in turn, should be more friendly to environment. The 2DS scenario envisages government initiatives to improve energy efficiency, which should be accompanied by a simultaneous increase in carbon dioxide payments and hold down the demand for energy. If the state does not take active measures to ensure energy efficiency, the demand for electricity will increase and the level of CO_2 emissions will exceed the average (reference) value foreseen in the 2DS scenario. In this case, achieving benchmarks will be accompanied by greening the supply (there is a decrease in the level of ESCII). And vice versa, if the actual level of energy efficiency policy exceeds the target one, then the ESCII will increase (IEA, 2013).

Thus, summarizing the above, one can confirm that energy-efficient sustainable development of any state is possible only if the sustainable development of all its regions is ensured and presupposes the formation of an effective structure of the country's economy while balancing regional interests.

Today, the demands of productivity, energy efficiency and competitiveness, which have become especially relevant during today's energy, environmental and financial crises, are increasingly deserving of attention in the world. More often, the energy development orientation is being redirected towards a “green growth” model, which combines energy-efficient socio-economic development and environmental sustainability. The main international instruments in the green economy are: the report “Global New Green Course” of UNEP (2009), “Europe 2020: A Strategy for Intelligent, Sustainable and Comprehensive Growth”, European Council Strategy, 2010 (European Comission, 2010), “Towards a Green Economy on the way to Sustainable Development and Poverty Eradication”, the summarizing report of UNEP for Government Agents

(UNEP, 2011), Report "On ways to green growth " (OECD, 2011).

In the case of Ukraine, the elimination of existing disparities in the levels of socio-economic development of the country's territory should be considered as the first steps towards the implementation of the clean energy concept. Thus, the Ukrainian regions with lower levels of development balance than average ones include the Ukrainian Polissya, Vinnytsia, Kirovograd, Poltava, Sumy, Kharkiv, Cherkasy regions, and with low levels - Donetsk, some areas of Dnepropetrovsk and Zaporizhzhya, southern regions of Lugansk. Transcarpathian, Ivano-Frankivsk, Lviv, Odesa regions and the southern part of the Autonomous Republic of Crimea are considered to be Ukrainian regions with higher than average levels of development.

In Ukraine, the transition to green energy requires structural reforms, in particular:

1) in economic policy: it is necessary to approve mechanisms for stabilizing the economy; to use the latest methods of economic development management (change of production model), aimed at reducing the eco-destructive load; to conduct an active agricultural policy; increase the stability of the social sphere; to provide practical activity of the clean energy concept; to create a competitive market economy of the country;

2) in environmental policy: it is necessary to guarantee the environmental safety of nuclear facilities; to minimize the negative effects of the Chernobyl nuclear power plant disaster; to develop alternative energy, to restore the ecological status of the rivers of Ukraine (including the Dnieper River basin) and the quality of drinking water; to build new and reconstruct existing municipal sewage treatment facilities; to reduce the

load on the Black and Azov seas; to carry out various measures to preserve and to improve the ecological status of landscapes;

3) in social policy: to keep the social justice principles, to increase the level of education and intellectual potential of the nation; to prevent impoverishment of the population through the restructuring of the social sphere, to reform the wage system, to reduce unemployment, to improve the mechanisms of granting state aid, to introduce compulsory social insurance systems; to improve the situation of children, young people, women, families; to improve the health of the population in the direction of life expectancy and mortality; to overcome poverty and to raise the living standards of Ukrainian citizens.

Almost all Ukraine's power plants were built in the mid-twentieth century (Darnytsa TPP - in 1936, Sumy TPP - in 1957) and continue to operate until this time. Unfortunately, the equipment of those power plants that have been in operation for over 50 years is still operating at full capacity today. As a result, the inefficient activity of Ukrainian thermal power plants is reflected in the quality of inhabitants' life in the surrounding territories.

The most urgent issue today is to define the optimum replacement time for existing power plants or to determine the optimum service life for new plants. As noted in (Myelectro, n.a.), service life is a period for active work of main assets, which depends on many factors: scientific and technological progress, price, cost, wear and tear factors, the personnel qualification level, the presence of similar types of equipment, demand for products, financial capacity of the enterprise, etc.

As the power plant extends its operation, its technical features are worsened, maintenance costs increase, and its efficiency decreases. In addition, the duration of each subsequent renovation increases with time, and the time between repairs is reduced.

The activity of exhausted power plants, which continue to operate, is inefficient in terms of economic feasibility and dangerous in terms of environmental and social impacts, as it increases the risk of accidents and decreases the efficiency. Obsolete equipment makes a threat to increase CO2 emissions. The age features of thermal power plants located in the European Union (as of 2015) are given in Table. 8.

The main factors on which the duration of coal power plants depend include shutdown frequency, attentiveness of personnel during the repair work at the stations, the possibility of their reconstruction, environmental standards. The shutdown frequency for coal plants is usually 5% (for plants with a life span of 10-20 years), and if the station is not upgraded, this frequency increases to 20% when the 40-year service life is reached.

On this basis, the International Energy Agency's experts have substantiated the main properties of power plants that produce energy products according to the technologies that most closely meet the requirements of sustainable development (Table 9).

TABLE 8. AGE DESCRIPTION OF THERMAL POWER PLANTS, LOCATED IN THE EUROPEAN UNION STATES (AS OF 2015)

Features of the thermal power plants	The average lifetime of power units	Capacity share operated for more than 35 years,%	Capacity share operated for more than 50 years,%
Coal thermal power plants	26	54	9
Gas-fired thermal power plants	12	17	1
Fuel-oil-fired thermal power plants	26	55	5
All energy units	21	42	6

Source: data from (FEEM, n.a.)

TABLE 9. MAIN FEATURES OF POWER PLANTS TAKING INTO ACCOUNT THE ELECTRIC-POWER INDUSTRY OF ALL COUNTRIES-MEMBERS OF THE INTERNATIONAL ENERGY AGENCY AND REQUIREMENTS OF THE SUSTAINABLE DEVELOPMENT CONCEPTION IN 2013

Parameters of the power plants	Nuclear power plant	The power plant with combined steam and gas turbine	Coal-fired thermal power plant	Wind power station	The power plant with an open gas turbine
Capital cost, dollars / kW of power	2500	650	1400	900	400
Power plant construction term, months	60	36	48	18	24
Power plant life, years	40	25	40	20	20
Power plant efficiency,%	85	85	85	28	1
Thermal efficiency (combustion heat) of a power plant,%	33	58	44	–	37
The cost of fuel, dollars / million British thermal units of heat	0,5	6,0	2,2	–	6,0
Operating costs, dollars / kW per year	65	25	50	20	20

Source: data from (IEA, n.a.)

Despite high CO2 emissions into the atmosphere and global warming, according to International Energy Agency experts' predictions, fossil fuels (eg coal) are considered to be the most promising fuels in electricity production. Due to this, the replacement of the exhausted power plants will be carried out at the coal-fired power plants with updated carbon capture technologies. The technical term of such power plants exceeds 40 years (FEEM, n.a.).

Despite the vector declared by the Ministry of Energy and Coal Industry of Ukraine on the transition to the implementation of the clean energy concept, Ukraine today remains the country with the highest carbon content in the emissions from power plant operations, as evidenced by the Table. 10.

TABLE 10. CO2 EMISSIONS FROM POWER PLANTS OPERATION PER GDP UNIT IN THE WORLD COUNTRIES IN 2014

Country	The amount of CO2 emissions per GDP unit, tonnes / billion dollars
Ukraine	483
Russian Federation	427
Republic of Poland	230
China	201
Canada	172
USA	162
Germany	111
Japan	104
All EU countries as a whole	107

Source: data from (Naftegaz, n.a.)

Such a high level of the eco-destructive impact made by power plants' operation in Ukraine, is caused by the high deterioration level of main assets of power plants and their continuation after the end of their service life. About 80% of gas pumping units were installed in the 1970s and 1980s, with average productivity of 22%; 97% of thermal power plant units have fulfilled their lifetime (FEEM, n.a.).

In Europe, new plants are usually equipped with facilities for the treatment of wastewater from sulfur compounds and emission controls, and therefore, at this stage, modernization is out of date for them. Projects aimed at increasing the service life of stations are more relevant to those countries where many plants with a great life span operate. For example, in Germany, one-third of the lifetime of a power plant is less than 15 years (NKPE, 2013). For power plants with a life span of 40 to 60 years, upgrading is recommended. In the UK, most plants started operating 30 years ago. Measures to reduce pollutant emissions require careful economic evaluation, especially for older plants, where changes in operating conditions may adversely affect the life of the plant's boiler.

Scientists of the International Energy Agency have shown that one of the ways to reduce CO2 emissions into the atmosphere is to increase the capacity of nuclear power plants that do not have direct emissions. For example, in 2000, most US nuclear power plants were rated as the most cost-effective, and some were even licensed to extend their validity to 60 years.

CHAPTER 2 COLLABORATION DRIVERS ON RENEWABLE ENERGY

2.1 Strategic prospects to use renewable energy sources

History demonstrates the necessity to implement new technologies to improve resource efficiency. In this direction, there is a growing trend in the role of renewable energy sources (RES) in the world. A model for imitation can be the leading countries in terms of energy use and production through RES. China takes first place in the world in terms of received and implemented RES indicators. The following countries are Germany, America, Japan, Brazil (Sawin et al., 2005, 2008, 2014, 2016, 2018, 2019).

According to the prospects for renewable energy sources implementation in the next 10 years, their growth is expected at 2.8% and electricity from renewable sources – 9.2% (Rozhko, 2010).

A number of factors influence renewable energy development. Reiche & Bechberger (2004) identify 5 of them: geographical, price (economic), political, technological, social. According to M. Beckberg, the first and third factors have a direct impact on the profit from the use of renewable energy sources. Geographical factors are of particular importance, and its indicators are very positive in terms of environmentally-friendly development of renewable energy. At first glance, the population density of the region is unrelated to the investment attractiveness of the RES industry, but to generate large amounts of energy through RES requires the availability of free space for the location of energy production facilities. Apart from solar panels, it is very difficult to use other renewable energy technologies within the city. Solar collectors in this sense are very convenient - for their location the surface of the roof on buildings is ideal, and in some cases the sides of buildings. Wind turbines can be used to some extent, but in most cases, the use of solar panels is more cost-effective.

All these factors influence the formation of the state's energy strategy. At the national level, associations are coordinated in a specific target area, and it is called the "energy strategy". It should be noted that at the state level the energy strategy should be formally stated and be clear, not have a double interpretation, and have success criteria for evaluating the implementation over a certain period. The term "energy strategy" can be applied at all levels: planetary, associations of countries or some states, regions or cities, enterprises on the microlevels.

When forming an energy strategy, the energy conservation and energy efficiency issues should be addressed with the help of environmentally-friendly investing, and in the current conditions to look for the most optimal combinations of conventional and RES systematically, rather than spontaneously, implement the latter. Talking about energy efficiency and energy conservation in the concept of energy strategy, we use the term "energy efficiency" as the effectiveness of the energy system, and "energy-saving" - as careful use of non-renewable resources and minimization of the negative impact on the environment.

The development of the energy market in favour of RES should be reflected in such indicators as the ratio of RES to GDP per capita (monetary dimension), the amount of RES to the total amount of produced energy (t. e. f.) and the potential amount of energy that can be generated in the country (region) at the expense of RES. Renewables can significantly reduce dependence on both non-renewable raw materials and external suppliers, which will increase the overall level of energy security of the country and the region.

2.2 Sources of the alternative energy resources

Alternative energy is constantly replenished, or its source is almost inexhaustible, as opposed to exhaustive resources such as oil, coal, natural gas and others. Another way to allocate energy resources is to separate conventional and non-conventional types of energy. It is customary to consider conventional energy sources as those types of energy that are widely used in human life. These include hydromechanical energy, organic and nuclear fuels.

The World Energy Council, comprising more than 90 countries, uses the classification of 16 types of energy resources and divides them into conventional / non-conventional as well as renewable/non-renewable (Dudyuk, 2008). It is known that in recent years special attention has been paid to solar (solar power plants), wind (wind power plants), geothermal energy and various types of biomass, so as early as 2020 some of these renewable sources can become conventional in the world.

SPPs have the highest growth rate of commissioned capacity in the world. Thanks to modern technologies, it is proposed to use solar energy as an alternative to fossil fuels. These technologies can be used both for domestic needs (individual use, roofs of buildings) and on a production scale. Direct conversion of solar radiation to energy can be achieved in many ways.

The main types of SPP include solar architecture, solar thermal systems and photovoltaics.

Conditional use of SPP can be divided into two groups: individual provision and large-scale energy production systems. The first group includes small SPP (on the roof of buildings, on our own territory, etc.) to meet, first of all, our own needs. Large-scale production systems include large solar panel "fields", which aim to sell the generated energy at a preferential rate to the overall energy grid and to get profits.

In publications, Tsoutsos, Frantzeskaki, & Gekas (2005) draws attention to the socio-economic benefits of SPP operation:
1. Increasing regional/national energy independence;
2. Providing significant work opportunities;
3. Diversification and security of energy supply;
4. Support for deregulation of energy markets;
5. Accelerating rural electrification in developing countries.
The consequences of the SPP use for the environment are:
1. Reducing greenhouse gas emissions and preventing emissions;
2. Restoration of degraded land;
3. Reduction of the necessary transmission lines of electric networks, while meeting the needs of remote areas (Tsoutsos, et al., 2005).
In the solar industry, major environmental risks are related to the use of a large number of toxic components in the photovoltaic converters producing process. In particular, PECs contain cadmium telluride, cadmium sulfide, gallium arsenide. Fluorine is used in the production process, which creates a number of toxic compounds. For this reason, it is important not only to pay close attention to the hazardous elements in order to prevent critical consequences but also to take these facts into account when assessing the negative impact of RES on the environment.
Large-scale electricity generation systems are based on thermal or photovoltaic technologies. Both approaches require large areas of land. This factor is less taken into account in individual systems, since in these cases the SPPs are located primarily on the roof of buildings, and in some cases on the walls. When choosing the location of SPP systems, consideration should be given to the land issue, namely its cost and the amount of solar radiation in the area. To reduce the cost for renting (buying) of lands, it is advisable to use remote areas of the country, where the cost to rent (buy) the land is

much lower than the cost of land close to the city. It is also better to use areas that are not suitable for agriculture or forestry.

Large-scale systems, or solar parks, require additional studies regarding the impacts on wildlife, as well as on the environment as a whole. Hötker, Thomsen, & Köster (2006) draw attention to the fact that solar parks have a possible potential impact, which is similar to the effects of wind parks on wildlife. These include the impact on animal reproduction and bird mortality due to collision with the surface of the SPP. Hötker, Thomsen, & Köster (2006) express the probability of the effect on waterfowl that migrate at night.

Similar problems are related not only to the SPP but also to the WPP. When operating wind turbines, birds suffer from collisions with their sails. This is noted by Abbasi (2000) in his study of the areas adjacent to the Blyth Harbor Windmill. They found about 1,000 dead birds, including rare birds. Hermann Hötker considers it necessary to conduct basic neurophysiological and behavioural studies in order to understand the birds' orienting mechanisms, which will prevent them from being adversely affected (Abbasi et al., 2000).

What is good is that the WPP does not require the use of water resources, unlike NPPs, SPPs and hydropower plants. From this point of view, WPP is the least energy-intensive source of energy. At the same time, the WPP has a significant drawback - the noise from the windmill, which affects the flora and fauna, as well as causing local inhabitants' dissatisfaction. Part of this noise has infrasound, which has frequencies below the human sound range. This infrasound can cause a vibration of buildings and structures. It is generated by wind turbulence and interacts with the tower. This factor is very important for Ukraine's regions where most buildings have been in operation for over 20 years.

It is possible to reduce wind velocity in large wind parks. The presence of large wind parks can cause indignation on the part of local residents, as the presence of windmills alter the aesthetic appearance of the landscape and in some cases may affect radio signals.
Another important factor for the WPP is the backup power source or its storage system. It is due to the instability of wind flows and the presence of "still", i.e. complete absence of wind. For this reason, it is advisable to have a storage system to store excess energy for use during peak periods. SPPs are less affected by this, but they also require energy storage systems, which impose additional costs with full autonomy from the traditional energy grid.
This problem is absent when using hydropower plants. As Egré, & Milewski (2002) note, hydropower has the highest availability, reliability and flexibility. Hydraulic units can be started, stopped or changed within minutes. For this reason, when there are enough water resources, hydropower can provide basic energy needs. As of 2016, hydropower accounted for 16% of world electricity production (Sawin et al., 2018). It is worth noting that hydropower generates the largest share of energy among RES. This is due to the fact that HPP technologies are used for a long time.
There are many types of power plants that are related to hydropower. The most common of these are HPPs with dams; HPP located near dams; derivative HPPs; hydro-accumulating power plants; small and mini-hydropower plants; tidal power plants and ocean thermal energy conversion stations.
In terms of the consequences regarding the use of the hydropower plants are quite controversial and have both positive and negative features. Large HPPs use dams, causing flooding of the area, endangering the habitat of animals and adversely affecting arable land. Artificial dams have a double effect. On the one hand, it is a change in the natural ecosystem

that has a significant impact on fish migration. On the other hand, new reservoirs provide new wildlife habitat.

Many studies have considered the impact of HPP on the environment, and they all agree that large HPPs cause serious adverse effects on the environment, especially for water quality (Abbasi et al., 2016). Some researchers (Harte et al., 1978) argue that HPPs are the most environmentally hazardous. In his research, Abbasi S. A. draws attention to the fact that there is a frequent increase in the incidence in areas where HPPs are used (Abbasi et al., 2000, 2016).

Large and small HPPs or mini HPPs differ in power. Small HPPs are considered to be such power plants with a capacity of less than 10 MW. The potential of small HPPs in several countries (Nepal, Madagascar, Papua, New Guinea and some Latin American countries) exceeds the total installed capacity of power plants by all other energy sources (Abbasi et al., 2000). The principle of operation in small HPPs is based on energy production through the construction of low-threshold dams, flow generators, or using natural flow if its capacity is sufficient. The effects of the low-threshold dams use in HPPs are the same with large ones but smaller in scale. For this reason, large-scale use of small HPPs will have the same effects as the construction of large HPPs.

Thermal waters, steam-water mixtures and natural steam have the best economic indicators among all types of geothermal energy. For this reason, this type of RES is sometimes negatively perceived by the community since industrial water smells hydrogen sulfide and is contaminated with ammonia, mercury, radon, arsenic and boron.

There are three types of geothermal resources: hydrothermal, dry hot rock, and geo-absorption. Today, only the first type of geothermal resources is implemented. The main producers of geothermal energy are the Philippines, New Zealand, Iceland and the United States. The total installed capacity is over 4,700

MW of electricity (MW) (World Resources Institute, 1988). Although geothermal resources are suitable for electricity generation, their use in the future should be linked to the combination of heat and electricity production.
Another type of RES is biomass. Biomass is divided into phytomass (plant mass) and living organisms (animals and microorganisms). Phytomass is used in the energy sector, so the further description will be devoted to it.
Phytomass, by its nature, uses solar radiation, water, and earth resources for its growth. According to the research, biomass can capture up to 15% of solar radiation (Abbasi et al., 2000). Johnson and Hinman (Johnson et al., 1980) estimated that in order 10% of the oil demand or 25 barrels of oil in a country such as the United States it is necessary to gather the harvest on 12 million hectares of land. Abbasi et al., (2000) notes in his work that it is estimated that about 4.2 hectares of land will be needed to refuel a car with biofuels in one year, while about 0.5 hectares is used to feed each person. In addition, demand for agricultural products will grow over time, increasing competition for land and water resources.
There are different variations of biomass projects. Today, one of the most popular is the cultivation of plants, trees and algae (phytomass), as well as the biogas production. The last of the above RES types is biomass. Biomass is divided into phytomass (plant mass) and living organisms (animals and microorganisms). Phytomass is used in the energy sector, so the further description will be devoted to it.
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There are different variations of biomass projects. Today, one of the most popular is the cultivation of plants, trees and algae (phytomass), as well as the production of biogas.

The implementation of most biomass energy programs will require significant amounts of water and land. Biomass production projects are likely to exacerbate soil erosion problems (Tandon, 1995, 1992; Gadgil, 1993). Modern technologies can significantly reduce the negative impact on soils, but this process is complicated by the technological complexity and difficulty of implementation.

Soil erosion contributes to a significant increase in water mileage, thereby delaying groundwater recharge, which has a direct impact on rivers and water quality, which in turn will change both habitat and food sources of wildlife and biota (Gadgil, 1993; Pimental et al., 1983).

Plantations of monoculturally growing trees change the habitat for many wildlife species (Pimental et al., 1983). These monocultures are less resistant than natural tree belt areas and require pesticides and fertilizers to increase growth rates. Large-scale use of fertilizers and pesticides will inevitably pollute water (Tandon, 1995, 1992).

Growing biomass can lead to health and safety issues. Agriculture has 25% more injuries per person per day than in all other industries. The production of forest biomass is several times higher than occupational injuries and illnesses than coal and oil production (Leigh et al., 1997).

Total employment is expected to increase if the demand for biomass resources increases (Pimentel et al., 1983). At the same time, manpower for agricultural and forestry work will be required to care and to gather harvest, transport and operate biomass facilities. The production of biomass fuel requires 3-7 times more maintenance staff than at the carbon fibre plant (Schneider, 2003). Growing corn to meet energy needs 18 times more manpower than producing an equivalent amount of petrol (Pimentel et al., 1984).

The most common technologies to convert biomass to energy are direct combustion and pyrolysis. It causes air pollution by solids, carbon monoxide, sulfur oxides, nitrogen oxides, carbon dioxide, toxic irritants, acids, aldehyde, phenol and carcinogenic compounds, such as benzopyrene. Generation due to solid waste leads to the appearance of ash, which sometimes contains toxic substances (Abbasi et al., 2000).

According to the traditional approach to the analysis of environmental and economic impacts of the energy sources using, the direct impact on the environment is evaluated. But there is a question of indirect environmental impact, such as TPPs and heating plants have a large number of emissions of harmful substances into the atmosphere. That is the reason why enterprises using this principle pay an environmental tax. In addition to their direct impact from their core activity, such enterprises use water (to wash away residual fuel and soot) and occupy a certain amount of land. Environmental loads must also be taken into account during the exploration, production and processing of energy resources to generate electricity.

2.3 Investment and cooperation mechanism in the renewable energy sources sphere

Analyzing investments in the RES sector, it is impossible to ignore the commissioned RES capacities indicator. According to the International Renewable Energy Report (Sawin et al., 2018), the largest share of generated energy belongs to large hydropower plants (HPP), but the increase in solar power capacity (SPP) indicates a potential change in energy structure in favour of solar energy (Fig. 2).

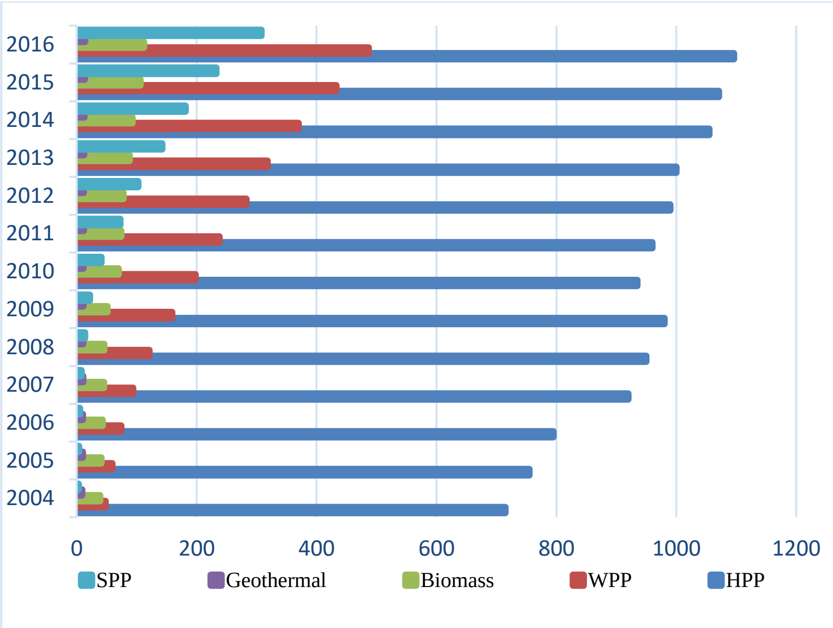


FIG. 2. INCREASE OF THE GENERATED ENERGY BY MEANS OF RES IN THE WORLD, GW*H PER YEAR

Source: data from (Lins et al., 2014; Sawin et al.,, 2015, 2016, 2017)

The increase in energy produced by RES has undergone significant changes in recent years. In 2004, about 48 GW was generated from wind energy, 39 GW from biomass, and 4 GW from solar power plants. In turn, in 2004, 781 GW was generated from hydropower plants. The total amount of generated electricity was approximately 3,800 GW, of which 160 GW was generated by RES, which is 4.2%. (Sawin, 2005) However, already in 2016, the total energy production of WPPs, SPPs and other RES is almost equal to the energy, generated by hydropower plants in the world. At this rate of growth in 2018, the capacity of the hydropower station is equal to the sum of all other RES.

The slow growth of the new capacity at the hydropower plants is due to the fact that the small hydropower plants occupy a longer coastline, which in turn increases the complexity of their maintenance. The construction of large (rowing) hydropower plants requires a large amount of financial and land resources and has a high level of impact on the environmental system. Construction of the dam for hydropower plant and minimization of the impact on the power plant is quite a difficult task and its solution requires clearly verified steps for implementation, which takes much time.

SPPs are more convenient in this matter because they can be located on the roofs of city buildings and in any plains. The amount of energy generated from the SPP is determined only by the number of sunny days and has a relatively predicted value. Another factor in favour of the SPP is the relative ease of maintenance and continuous development of photo-elements technologies that capture solar radiation. It makes these technologies cheaper and more productive. A good example is Germany, which has a leading position among European countries and, according to the 2016 RES global report, takes third place among countries in the world, behind China and Japan. (Sawin et al., 2018) It should be noted that these indicators are very important when comparing the amount of solar radiation in these countries with other countries in the world. According to the solar radiation maps of the country, Africa, Saudi Arabia, Yemen, UAE, Chile, Mexico, Oman and others have much greater potential for the introduction of SPP (Solargis), but none of these countries is among the leading countries in the production or implementation of SPP (Sawin et al., 2018).

Integration of SPP in cities is capable to meet more than 60% of the total energy demand, calculated by Amado et al. (2014), J. Hofierka et al. (2009), if only the roofs of the most suitable buildings are taken into account, this figure will be 19.7-31.1% of daily consumption and 47.7 to 94.1% of market peak power in the grid, as exemplified by Mumbai, India (Singh et al., 2015).

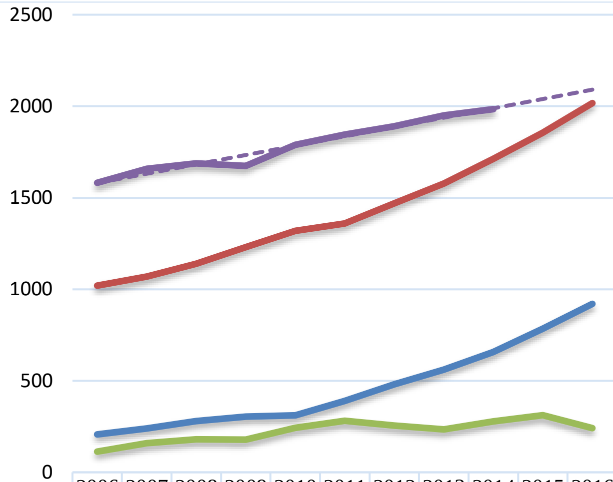
According to D. Dodman's study, cities consume approximately 75% of the energy produced worldwide (Dodman, 2009). The integrated local energy generation at the consumption site can significantly contribute to the environmental, economic and social aspects of urban-oriented environmental development. Adil et al. (2016) highlighted four advantages of such distributed energy systems:

1. Significant reduction of carbon emissions into the atmosphere;
2. Compensation of investments for the modernization of grids;
3. Provision of local energy independence and grid security;
4. Motivation, popularization of social capital and cohesion of the population (Adil et al., 2016).

According to Wang's et al. (2015) estimates, heating accounts for up to 50% of global energy demand. His research focuses on hot water needs and he offers solar hot water systems. The thermal energy of such systems (up to 240 W / m^2) is higher than the energy of solar heat collectors (67 W / m^2) (Smil, 2015). The cost of water heaters is quite moderate and the Chinese researcher H. Wei has proved that 84% of urban households in China can install an autonomous water heater system (Wei et al., 2014).

Seasonal solar thermal energy storage technology is based on the principle of storing heat power excess in the summer season to meet the heat demand in the winter (Kammen et al., 2016). Such technology is able to meet 90% of the total needs of a large apartment building (Terziotti et al., 2012).

Investment in the renewable energy sector in the world had a positive trend since 2004 (Fig. 3). Even during the 2008-2009 global crisis that began with the US real estate market (Sawin et al., 2018). Investments in the RES sector have remained virtually unchanged and remained at the same level - $ 3 billion in 2009 in relation to the indicator in 2008, and the following year the increase was $ 66 billion.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total power without HPP (GW)	207	240	280	305	312	390	480	560,5	657,2	784,7	920,3
Total power with HPP (GW)	1020	1070	1140	1230	1320	1360	1470	1578	1712	1856	2017
Total investent (billion $)	113	159	181	178	244	281	255	234	278	312	242
World electricity consumption (million tons)	1582	1658	1688	1675	1790	1845	1890	1950	1984		

FIG. 3. INVESTMENT TO RES IN RELATION TO THE RES TOTAL INSTALLED CAPACITY

Source: data from (Sawin et al., 2018; IEA, 2016)

Although investments in the RES sector have some fluctuations, the indicator of the amount of input capacity from RES has been growing rapidly since 2010. It is due to the improvement of technologies used in the installation of new facilities and research in this direction. For example, over the period 2010-2015, the cost for installation of SPP decreased by 50% (Orr, 2015). This fall in value has been made possible by the steady development of technology.

Fethi Amri (2016) looked for and explored the relationship between direct investments that were aimed at generating energy through both renewable and non-renewable energy sources. He also compared three groups of countries (all countries of the world; developed countries; developing countries) for the period 1990 - 2010. Renewable and non-renewable energy categories were analyzed for these groups of countries (Amri, 2016).

Fethi Amri (2016) has made several conclusions from his research. First, the development of RES leads to economic growth. The second, the relationship between RES and economic growth means that the development of the RES market has a positive impact on production.

It was found out that direct investments increase the consumption of non-renewable energy. Also, in most countries, the relationship between the development of renewable energy and direct investment can be traced. It means that renewable energy plays a vital role in attracting foreign direct investment (Amri, 2016).

Bhattacharya et al. (2016) conventionally divide 38 countries into three groups based on an analysis of the relationship between the economic growth of renewable and non-renewable energy sources from 1991 to 2012.

The first group of countries includes Austria, Bulgaria, United Kingdom, Greece, Denmark, Italy, Canada, China, Kenya, Morocco, Netherlands, Germany, Norway, Peru, Poland, Portugal, Republic of Korea, Romania, Chile, Czech Republic, Finland, France. RES form an important factor in economic growth for the first group of countries. As it was mentioned above, most countries support the development of renewable energy at the political and legislative levels. Examples of such documents are the Renewable Energy Act of China (2007), EU Directive 2009/28 / EC on the promotion of energy from renewable sources (2009) and others for each country. The development of RES in the world leads not only to economic growth but also creates new jobs. At the end of 2016, the total number of jobs in the world reached 9.8 million (Sawin et al., 2018).

In the second group of countries, according to Bhattacharya et al. (2016), there is a situation where the RES introduction coincides with the deterioration of economic performance over the studied period. The group includes the United States, India, Israel and Ukraine. All countries in this group are highly reliant on non-renewable energy sources. For example, India's energy sector is predominantly coal (69%) and only 12% is hydropower. In the Ukrainian electricity market, more than 80% is produced through Comprehensive Energy Resources (NEURC).

In the US, natural gas and coal account for 67% (Bhattacharya et al., 2016; Dogan et al., 2017; World Bank Data Base). The United States is one of the leading countries in RES investment and commissioned capacity, playing a significant role in the global arena and international markets.

The following eleven countries were included in the third group: Australia, Belgium, Brazil, Ireland, Japan, Mexico, Slovenia, South Africa, Sweden, Thailand and Turkey. For this group of countries, RES is not an impediment or a driving force for economic growth. Bhattacharya et al. (2016) explain this situation by the inefficient use of RES in the production process. In order to get benefits from the RES implementation, third group countries are advised to focus on increasing investments in the RES sector and removing barriers or obstacles to the RES implementation. Australia aims to produce 33,000 GW, equivalent to approximately 23.5% of Australia's total energy supply, in its RES objectives (Sawin et al., 2018) in 2020.

In order to achieve the goal of energy intensity optimization, it becomes necessary to optimize the energy production structure and to take into account its impact on energy indicators during the energy sector development. According to the World Bank database, the world's largest source of energy consists of exhaustive resources (Figure 4). The annual growth of electricity demand cannot be fully satisfied by a single source of energy, that is why the absolute value of electricity production is increasing. It should be added that the relative value of RES is increasing and the amount of energy produced from exhaustive resources is decreasing, indicating that RES meet most electricity needs in the world. One can see the relationship between the relative share of RES in the structure of energy production and how much the country is developed in a more detailed comparison in the energy production sector in the world. It means that in developed countries (USA, Germany, China, other countries in Europe), RES volumes have a faster growth rate than in developing countries (Ukraine). This dependency is explained by greater financial freedom and the ability of residents from developed countries to invest in RES compared to residents of developing countries.

The next step in the possible development of market relations may be joint cooperation between countries, or countries and private enterprises. According to this scheme, renewable energy production will be implemented on a large scale not only in the developed countries but also in developing ones. This approach will let to use production facilities more effectively.

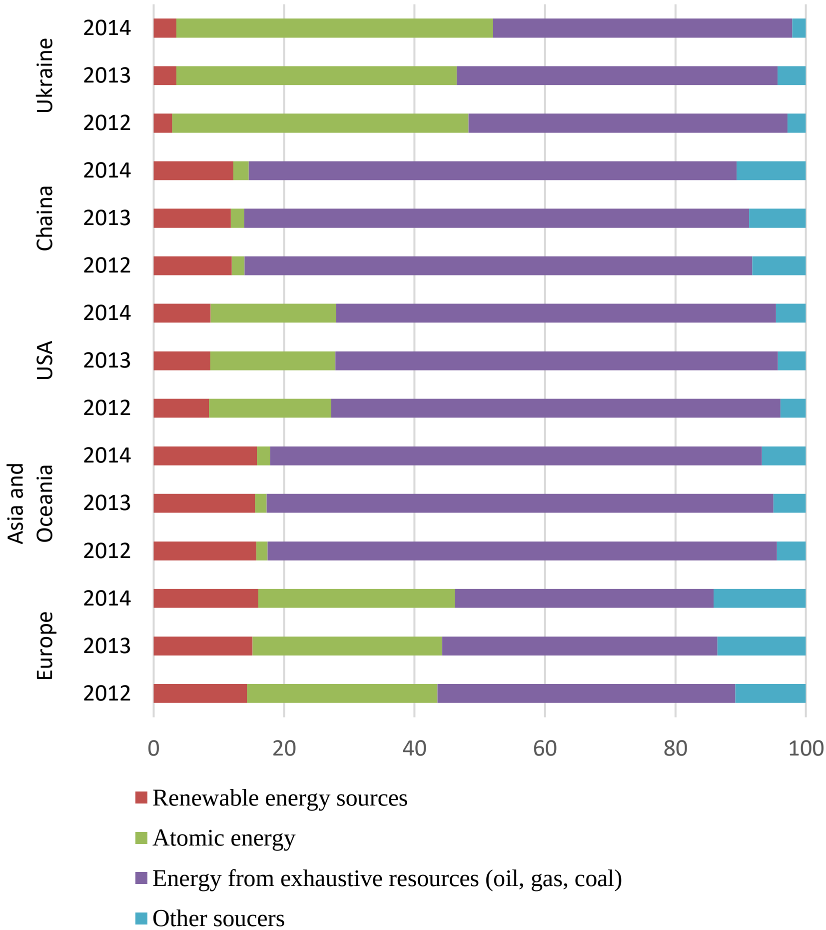


FIG. 4. STRUCTURE OF ENERGY PRODUCTION IN THE WORLD

Source: data from (World Bank Database, n.a.)

Agents of the proposed scheme may be individuals, a group of individuals, individual enterprises or a group of enterprises, local governments and public authorities, international associations and foundations.

Global trends in the development and popularity of the RES introduction lead to answer the question of how a full-scale transition from the traditional model of energy supply to the systems of energy interaction at the expense of RES should be made. The next international report on the renewable energy implementation in 2017 proposed and discussed the transition from a baseload paradigm to a 100% renewable energy paradigm. This paradigm stimulates certain areas related to the energy market.

In the first stages, switching to RES will only compensate peak values in the country's needs, usually from about seven in the morning until half-past nine. The periods of wind energy activity increase are in the night hours and the solar ones - usually from eight to eight.

Further transition is gradually complicated by the exclusion of facilities that consume exhaustive resources from the main power grid of production. At the forefront, there is a problem regarding the distribution and satisfaction of peak demand. It requires the accumulation of excess energy during the reduced energy demand periods, its storage and usage during increased activity. A possible solution may be to use imported energy during peak activity from one country to another, which has energy excess (or a period of low activity). Most production operations are about electricity, as the highest quality form of energy that is most common, easily transported, and converted to the right type of energy at the final consumption site.

With the transition to 100% renewable energy in the energy system, electrification of heating, cooling and transportation is required, and one of the main tasks is to accumulate and to store surplus electricity and to use it in the shortage conditions (Sawin et al., 2018).

When connecting RES to the core power grid, infrastructure, maximum and minimum demand ("critical points") for energy during the day and seasons, efficiency and regulatory barriers of the country should be taken into account. Desideri et al. (2012) draws attention to this. Summarizing the above, the use of RES in the world can be identified by the following benefits:

- reduction of the load on the environment by decreasing the emissions of harmful substances to the atmosphere and the exhaustive energy resources use;
- meeting the goals of sustainable development;
- ensuring local energy independence and power grid security;
- motivation, popularization of social capital and cohesion of the population.
- the constant development of technologies that leads to a decrease in the cost of RE equipment and, at the same time, to the efficiency factor of this equipment.

It is related to:

- the destructive impact on the environment in the current structure of energy production (TPP, NPP);
- the exhaustiveness and scarcity of conventional energy resources, the volume of which is decreasing and the cost is increasing;
- dependence on conventional energy production sources in the overall structure of energy production;
- significant logistical costs or remoteness of cities-consumers from energy production sites;

It is important to solve the problem to find investment partners and to develop investment scenarios for different entities in RES development. The task for investment search can be solved through cooperation at different levels.

At the country level (international level), where agents are countries or groups of countries, private enterprises or associations of enterprises, foundations and the co-operation of their resources to achieve their own goals through the RES implementation.

At the country or regional level, agents, individuals and their associations, local authorities and the state's policy on the development of renewable energy are added to the previous level.

CHAPTER 3 CONCEPT OF ENERGY COOPERATION IN EUROPE

3.1 Preconditions for energy cooperation in Europe

Energy cooperation in Europe was carried out with the development of technology in the energy field. The first energy grids in Europe were built from the late nineteenth century. And since they have operated, there was a wide diffusion of development and research. Engineers' and electric cartels owners' enthusiasm was directed to the promotion of electrical services and energy networking. Energy opportunities have been widely discussed at international meetings by many organizations, including the League of Nations, the International Labour Organization, the International Electrotechnical Community, and others. The economic benefits to using an energy mix of resources that consisted not only of financial savings, but also of better utilization of plant capacity, and of the increased relationship between industrial regions and countries, on sessions and conferences. However, in the early twentieth century in Europe, there were significant contradictions both in the prewar and interwar period. Owing to numerous conflicts, energy networking has become more difficult. Local grids were deployed at national and regional levels. And despite the numerous calculations on the benefits of exchanging energy between countries in the presence of surpluses and energy shortages, the increase in grid length has been slow enough.

In the '20-'30s of the twentieth century, there were several plans to build electricity networks in Europe. George Viel introduced the continental European network concept, Oskar

Oliven has developed a scheme of European superpower system in Europe. However, there were numerous obstacles on the way to the European electrical system. And there were problems not only caused by the need for major capital injections for energy infrastructure reform but also by significant differences in the laws of the countries, ways of regulating the energy production and transmission sphere at national levels, technical characteristics of the networks. Most important thing is that the political environment of that time did not encourage the creation of networks promoted by initiative groups. Less developed countries were not ready for such large-scale adjustments. As a result, the plan for the European Continental Electric System was only partially implemented after the end of World War II (Schot et al., 2008).

In the 1950s, associations and organizations that aimed at managing the systems of countries' electrical grids in different regions of Europe, were formed. One of the most powerful organizations should be called the Union for the Co-ordination of Production and Transmission of Electricity (UCTE). Initially, the organization provided the combination of grids of only three industrialized countries (Germany, France and Switzerland), but in the future, it was significantly expanded. Other organizations are gradually emerging, including the Baltic Sea Group Associations (BALTSO), Britain and Ireland (ATSOI UKTSOA), Finland, Norway, Sweden and Eastern Denmark (NORDEL).

However, the idea to connect grids across Europe, including its Eastern and Western parts, was not fulfilled during the Cold War. The pan-European electricity grid idea remained unfulfilled. When the Soviet Union was collapsed, such plans became possible (Simões et al., 2012). That is why the European Transmission System Operators Association (ETSO) was created in 1999, and in 2009 it was reorganized into the

European Network of Transmission System Operators for Electricity (ENTSO-E). ENTSO-E has joined regional network operators and is now coordinating the work of 43 operators from 36 countries in the world (ENTSO-E, 2019).

Despite significant steps towards the deployment of the pan-European electricity market, there are still some challenges. It is necessary to adapt the electricity system in Europe in such a way that it is possible to integrate renewables into a single system. And then renewable electricity can be freely transferred to energy demand regions (Tröster et al., 2011). It means that it is necessary to construct smart grids.

According to Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006 / EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009 4 priority areas for smart grid deployment are currently being considered in the EU:

- between France and Germany (Smart Border Initiative);
- between Italy and Austria (ALPGRID);
- between Slovenia and Croatia (SINCRO.GRID);
- and between the Czech Republic and Slovakia (ACON).

The deployment of smart energy grids is vital to ensure the integration of distributed renewable energy sources into a single energy infrastructure and increase energy efficiency in all sectors of the economy.

3.2 Infrastructure aspect of the deployment of smart grids

The deployment of smart grids, as one of the key areas of global energy development, and as an integral part of integrating technologies in different areas to create a smart, comfortable and environmentally friendly environment, requires not only purely technical solutions.

Ensuring that progress can be made towards the construction of the smart energy grids depends on the related industries development. In this context, there are several areas that need attention as such, which depend not only on the pace of smart grid technologies introduction but on the further way of their development. There are currently several key issues that need to be solved to accelerate the development of a smart energy grid as one of the dominant components in the energy system. It indicates that the future development and smart energy technologies scaling may vary significantly in the future. Today, the major work on the smart energy technologies implementation is to provide the basis for the further implementation of innovative solutions. However, it is impossible to say what these decisions will be. Until the issue regarding load balancing (and therefore capacity) in an electricity grid that uses renewable energy sources is resolved, it is impossible to talk about an efficient and large-scale energy system. This is due to the fact that alternative (renewable) energy is not able to solve the key task for the modern grid, namely to provide the consumer with the required amount of electricity at the right place and at the right time. It explains the significant role of conventional powerful energy producers in the energy system and hinders the pace of energy innovation through a smart grid concept. In such circumstances, there is no other rational decision for the stakeholders than to carry out a gradual renewal of the grid with a small list of applied technological solutions. That is why the European Union's energy policy implies the existence of modernization stages, and more precisely of energy network transformation, where the first stage provides preparation for the further deployment of energy innovations. It explains a significant number of projects on smart metering devices. It is the basis without which further implementation of smart energy technologies is impossible for grids. And this is the reason for the lack of large-scale activities to implement complex energy-efficient projects for the deployment of smart grids in a large area. The effectiveness of such projects may differ significantly from expectations, as evidenced by a number of low-performing projects that have been implemented by leading countries in the world. Despite the great importance of pilot projects for the smart grids modelling, the identification of problematic issues and the practical validation of technological solutions in working conditions in relationship with other technologies, they cannot be considered as a first step towards the transition to the second stage of the smart grid deployment. At the same time, the information obtained from their implementation demonstrates the necessity for thorough preparatory work before the systematic deployment of smart energy networks at both global and local levels.

The first stage of the smart grid deployment can be considered in two aspects. First, it is a stand-alone phase that involves the implementation of a large number of technological solutions and is characterized by scale and inclusiveness, both in the territory and in terms of the number of energy generation, energy distribution, energy transportation and energy consumption objects. The above holds true for the European Union and the United States of America as territories where the above stage is practically complete. Secondly, the content of the first stage of the smart grid deployment gives reason to talk about its infrastructure orientation. It is a prerequisite for further activity in this field. It means that it is an auxiliary stage. A time of serious innovation and major projects that can be the starting point for the transfer of energy innovations to build smart grids has not come yet. It is proved by the unresolved technical and technological problems discussed above, namely that the issue of balancing the grid with distributed energy generation on the basis of widespread use of renewable energy has not been resolved. It creates significant constraints in the implementation of strategic plans for the energy grid transformation and the transition to a qualitatively new energy system. Given this background, it is possible to single out the issue of technical infrastructure as one of the constraints, despite the considerable amount of work being done in the first phase of the transition to smart energy grids, which has been undertaken in leading economically advanced countries in the world.

Thus, the development pace of smart grids depends not only on the implementation velocity of the measures provided in the first stage but also on the solution of the described technical and technological problems. It indicates a fact that there is a certain limit that can be reached today, but beyond which it is now impossible to cross in terms of economic feasibility. Since the implementation of global grid development projects may now lead to their inefficiency in the future due to differences in the used technologies or the low synergies that will be obtained by combining the results of individual projects into a single global grid. Accordingly, the feasibility to make great investments in global smart grid development projects for the emergence of commercially viable technology products that solve unresolved technological problems today is questionable.

However, the technical infrastructure is not limited by energy means. Some other factors are critical to implementing the smart grid deployment concept. One of them is to develop information and communication technologies. Information is a key issue in many areas. The functioning of almost all systems used to meet the social needs, to ensure its proper functioning in accordance with the ever-growing requests and requirements put forward to work with information as it grows, the development of technology, the total digitization of most human activity areas depends on the quality of work with it. The creation of decentralized systems requires considerable information and communication capabilities to achieve, on the one hand, the required level of controllability and, on the other, the ability to self-regulation. The future model of the energy system undoubtedly envisages a decentralized system with a high degree of self-regulation.

Therefore, the issue to provide information and communication support and maintenance of energy networks is a key problem that must be properly solved for the large-scale deployment of smart grids. Unlike the previous aspect of infrastructure provision, which was discussed above, namely: technical and technological energy infrastructure, information and communication support for the implementation of the smart grid concept allows counting on a high level of satisfaction of the vast majority of requirements that are being put to it. A major factor in this is the availability of a large number of information systems as commercial products that serve energy facilities and provide a rapid exchange of information, its accumulation and storage, processing and extensive analytical capabilities. The prospect of the energy market, given the transformational processes that are currently occurring and intensifying in the future, contributes to the improvement of information and communication technologies oriented to the requests of the energy system subjects.

At the same time, the functioning of information and communication systems is inextricably related to security issues. Creating reliable information systems is a key task for any software developer. Security noncompliance causes not only the vulnerability of objects that use information products but also causes serious damage to information system developers. Great requirements are imposed on information systems serving the energy sector. It is due to their significant importance for the normal functioning of society. A power grid failure in most cases causes significant losses, the elimination of which, or compensation for losses that occur in the event of a failure, requires considerable financial resources and sometimes is not measurable in the case of human death. Therefore, the security issue is extremely important in the energy sector. Each of the aspects to ensure the security of the energy system, including the grid, requires a considerable amount of work and specialists' coordination in different industries. Today, there is a situation where the issue of power grids security is at a controlled level, as evidenced by the low frequency of technical problems that cause significant damage. The pilot projects implemented in the leading countries of the world in the smart grid deployment do not give grounds to talk about the insufficient level of security of the information and communication systems that have been used. It concerns both the aspect of control over the technical parameters of the system, the quality of which is measured in terms of the failures in the system or its individual components, as well as the security of internal information. Thus, it can be argued that the information and communication systems used in the energy sector are in compliance with the demands and requirements that are put forward in the process of reforming the energy system, including in terms of implementing the concept of smart grid deployment.

However, the information and communication infrastructure as an element of the energy system needs more consideration. It is not enough to assess the compliance of modern information technologies with the requirements and needs of energy facilities. In practice, the implementation of projects to transform the energy system is guided by public requests under the influence of changes taking place in society. For example, several decades ago, energy development projections were based on the assumption that energy consumption in the world would decline over time, as new devices and technologies would require less energy, which would be driven by better performance, including lower energy consumption. Thus, it was assumed that the need for energy generation would gradually decrease. However, as the practice has shown, these predictions were wrong. Although they are based on the correct assumption of improvements in machinery and equipment, there is no steady downward trend in energy consumption in the world. This is due to the emergence of a much larger number of appliances that need the energy to operate them than they used to. The tendency for more devices and gadgets to cater to the needs of society as a whole and of individuals, in particular, is growing. Thus, there is currently no reason to predict a reduction in energy consumption in the short and medium-term. It means that the amount of generated energy must remain at a high level to ensure the proper functioning of society.

The production of all new equipment, devices and gadgets, indicates the new needs that were not relevant in the past. Digitization of almost all spheres of human activity creates new challenges for the energy sector. The implementation of the smart home concept was the first challenge for the energy sector. Right now, it's about creating smart cities. This global challenge requires a change in the traditional model of energy supply. It means that the information systems used to implement the concept of a smart city must have a high level of relationship with information systems that serve their own energy system. Therefore, a new aspect has appeared, in which information and communication systems need to be considered not only as an element to ensure the functioning of the energy system but as a certain element that is a response to public inquiries as a result of technological progress, which defines the directions of energy development as a key area to provide a normal social life.

A separate issue of infrastructure provision for transformation processes in the energy sector is the environmental component. Within the framework of the traditional model of the energy system, environmental infrastructure was foreseen as the presence of objects and technologies that reduce eco-destructive environmental impact by eliminating excess emissions of harmful substances entering the air or other natural spheres due to the functioning of energy-generating facilities energy resources for energy generation. Nowadays, much of the world's energy comes from renewable sources. Under the Paris Agreement by 2050, states-signatories are required to provide 100% renewable energy generation. The plans of the European Union by 2030 provide for the generation of renewable energy at 32% of the total. Deployment of the smart grids is one of the areas that contributes to achieving this indicator, because they provide the principle of distributed energy generation, without which the rapid growth of the share of renewable energy is doubtful. It is due to the fact that at this stage of the development of alternative energy, a significant number of energy-generating objects belong to medium or low power generating facilities. Therefore, it is economically feasible to increase the number of low-power energy objects in close proximity to the consumer and to use technologies that allow the end consumer not only to consume energy but to produce it, generating a surplus to the grid. The first phase of smart grid deployment, which has actually been completed in the European Union and the United States of America, as discussed above, is aimed specifically at providing the technical capability for this type of energy consumer interaction and building a new model of the energy grid that is fundamentally different from the traditional which was dominant during the XX century and at the beginning of the XXI century. In this way, the deployment of smart energy grids implements a new principle of human-environment interaction - to prevent eco-destructive environmental impacts. This is fundamentally different from the previous approach, which was to minimize the already done damage.

In addition to providing infrastructure to develop smart grids, consideration should be given to a factor that underestimates can significantly impede this process. It is about inertia and differences in the interests of the parties involved in the process. The inertia of the population to set capacity for energy generation to meet their own needs and to realize the produced excess energy can significantly affect the achievement of strategic plans. Therefore, organizational and informational work with the participants in the grid is important. It also concerns stakeholders: public authorities, energy generating companies, distribution companies, manufacturers of innovative energy equipment and more. Lack of balance can significantly affect the deployment of smart grids.

3.3 State support for innovative transformations in the field of energy security

Energy security is one of the key areas of national security. A stable and sufficient supply of energy resources is the key to the successful and efficient functioning of all sectors in the economy, providing the welfare of the population. At the same time, the considerable energy intensity of the industry, low energy efficiency in many spheres of life can lead to significant losses of energy resources and consequently financial losses both at the state and at the level of economic entities and households. That is why there is a necessity to make greater use of renewable and alternative sources of energy, as well as the full implementation of innovative energy-saving technologies at all stages of the transportation, distribution and use of different types of energy. In this way, it is possible to provide the necessary level of the state’s energy security.

Considering the case of Ukraine, the issues of energy security are extremely urgent and require the search for new alternative energy resources. This problem is increased by the high energy intensity of the Ukrainian industry, housing and communal services, transport and agriculture. For example, the fuel and energy cost of Ukrainian goods is between 10 and 80% of their prime cost. This indicator is several times higher than in the US and most European countries (Yefimtseva, 2014).

Over the last decade, there have been positive trends in the Ukrainian economy in reducing energy consumption. Thus, energy consumption in industry, households and in the non-energy use field decreased significantly (Table 11). Certainly, this is partly explained by the loss of production capacity and a large number of households due to the military conflict. At the same time, new energy-efficient innovative technologies are increasingly used in various fields, contributing to the reduction of energy consumption.

Positive shifts in the direction to increase energy security are evidenced by the gradual decrease of GDP energy index. At the same time, the energy consumption of Ukraine's GDP remains the highest in comparison with other European countries. The strategic plans of the Ukrainian government plan to reduce this indicator in 2025 to 0.18 T.O.E / $ 1 thousand, and to 2035 to 0.13 T.O.E / $ 1 thousand.

The constant decline in energy consumption is primarily due to innovative transformations in both the energy generation and consumption sectors. According to Bloomberg New Energy Finance, a prediction investment in new generating capacity in the period 2016-2040 will amount to $ 10.2 trillion globally: where 72% ($ 7.4 trillion) are renewable energy sources, of which $ 2.8 trillion - solar power, $ 3.3 trillion - wind power. Investment in renewable energy sources will reach $ 400 billion annually by 2040. Also, in 2017-2040, China and India generally invest $ 4 trillion in the energy sector. Solar and wind power account for 48% of the world's total power capacity and 34% of electricity (as of 2040). The energy, generated by solar power plants will be increased 14 times by 2040, and wind power 4 times (Na chasi, 2017).

TABLE 11. FINAL ENERGY CONSUMPTION FOR 2007 – 2017 (THOUSAND T. O.E.)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[2]
Total final energy consumption	85955	83283	67555	74004	75852	73107	69557	61460	50831	51649	50086
of which											
Industry	32852	30942	22629	25327	26253	24845	21864	20570	16409	14955	15103
in %	38,2%	37,2%	33,5%	34,2%	34,6%	34,0%	31,4%	33,5%	32,3%	29,0%	30,2%
Transport	15417	15141	12396	12627	12611	11448	11280	10327	8750	9165	9768
in %	17,9%	18,2%	18,3%	17,1%	16,6%	15,7%	16,2%	16,8%	17,2%	17,7%	19,5%
Households	23001	22845	22084	23813	23604	23466	23495	20384	16554	17588	16435
in %	26,8%	27,4%	32,7%	32,2%	31,1%	32,1%	33,8%	33,2%	32,6%	34,1%	32,8%
Service sector	4956	4952	4176	4643	4802	5037	5745	4663	3838	4856	4396
in %	5,8%	5,9%	6,2%	6,3%	6,3%	6,9%	8,3%	7,6%	7,6%	9,4%	8,8%
Agriculture, forestry and fishery	2018	2107	1994	2036	2246	2195	2242	2016	1961	2143	1870
in %	2,3%	2,5%	3,0%	2,8%	3,0%	3,0%	3,2%	3,3%	3,9%	4,1%	3,7%
Other activities	0	0	7	10	327	0	0	0	0	31	0
in %	0,0%	0,0%	0,0%	0,0%	0,4%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%
Non-power use of the energy	7712	7295	4269	5547	6008	6116	4932	3500	3318	2910	2515
in %	9,0%	8,8%	6,3%	7,5%	7,9%	8,4%	7,1%	5,7%	6,5%	5,6%	5,0%

Source: data from State Statistics Service of Ukraine (n.a.)

Today, Ukraine takes one of the last places in the world in terms of the use of renewable energy sources. Thus, in 2017, the share of renewable energy sources was 7.9%, which is significantly less than in most European and world countries. For example, in Norway this index is 97.9%, in New Zealand, it is 81.4%, in Sweden it is 57.5%. At the same time, the share of wind and solar energy use in electricity production in Ukraine is 0.99%, which is much less than for example in

Spain - 22.8%, Germany - 22.3%, Portugal - 22.1% and other countries.

Thus, there is considerable potential for innovations in renewable energy in Ukraine. This opportunity will be implemented including through the proliferation of batteries and other means that increase the flexibility of energy systems. The cost of generating electricity is predicted to decline by 66% in solar power generation by 20%, by 47% in the continent wind power, and by 71% in the offshore wind energy sector. The key role will be given to innovations in small-scale distributed generation, that is, to the introduction of individual solar panels. Thus, according to predictions, in 2040 in Australia small-scale solar power plants will produce 24% of electricity, in Brazil - 20%, in Germany - 15%, in Japan - 12%, in India and the United States - 5% (Na chasi, 2017).

State incentives for the renewable energy introduction in Ukraine since 2008 have been implemented in the form of a "feed-in tariff" linked to the euro. Moreover, the requirement for obligatory content of the "local" component was abolished, instead of which a surcharge for the domestic equipment use was introduced, as well as an incentive tariff for the production of heat from renewable sources, including biomass. The new Law on the Electricity Market regulates the responsibility of green electricity producers for imbalances (Dixigroup, n.a.).

Experts point out that the "feed-in tariff" is no longer satisfying the conditions of the renewable energy market and, to some extent, poses a threat to this market. The introduced feed-in tariff to stimulate the energy market has done its part by intensifying investment activities and increasing the attractiveness of green technologies. Today, such a system of incentives has lost its effectiveness due to the fact that it does not take into account the existing tendencies for cheaper technologies existing in the world and in Ukraine and increase of competitiveness in the renewable energy market (LIGA, n.a.).

New relations between producers of renewable electricity and its state are regulated by the new Law "On Amendments to Certain Laws of Ukraine on Ensuring Competitive Conditions for Generation of Electricity from Alternative Energy Sources" of 25.04.2019. No. 2712-VIII, which entered into force on May 22, 2019 (Verkhovna Rada of Ukraine, 2019). This Law provides support for renewable energy projects through green auctions, which, unlike the feed-in tariff, are designed to reduce the burden on electricity prices.

Besides, the key advantage of “green” auctions over “feed-in” tariffs is to create competitive conditions to support renewable energy projects, and conditions for healthy competition between renewable energy market participants at a lower cost. It should lead to the achievement of a balance between interests in the energy market while ensuring the further development of renewable energy and reducing the burden on electricity prices (LIGA, n.a.).

The transport sector has significant innovation potential in the whole world. The greatest prospect is the spread of electric vehicles, from the point of view of energy security ensuring in this area. According to experts’ data, the role of electric vehicles in the energy infrastructure will increase significantly in the near future. Their share will reach 13% of generation in Europe and 12% in the US. The scale effect will help reduce the cost of car batteries by 73% over the next 10 years. Ten-fold annual growth of the $ 20 billion battery storage market is projected to play a significant role, with small energy storage systems accounting for 57% of the world's energy storage capacity by 2040 (Na chasi, 2017).

The world practice of electric transport development has in the arsenal several types of state support to form the development of the electric vehicle market. Direct subsidies are most commonly used, i.e. one-off payments when buying a car (Germany, France, UK, US, Sweden, etc.), and fiscal preferences, such as tax cuts when buying or using an electric vehicle (Japan, Sweden, Norway, Denmark, China, etc.) (Pysmenna, n.a.). For example, in Germany, when you buy an electric car the subsidy is now € 4,000, for a hybrid car they pay € 3,000. This money is allocated in equal parts by the state and automakers. Nowadays, the Federal Economy and Export Control Administration has received about 118,000 applications for subsidies for the purchase of electric vehicles (Pysmenna, n.a.).

Today, levers of the fiscal method to regulate the market for electric vehicles are being used in Ukraine. The VAT on import of electric trucks by 2022 has been abolished. In addition, by 2028, an income taxpayer may include the cost of purchasing an electric vehicle or retrofitting with a tax rebate, and individuals who purchase electric vehicles are expected to be exempt from compulsory retirement insurance.

One of the main problems of the modern energy sector in Ukraine consists of losses in energy grids. Thus, the current losses in the electrical networks are over 12%. Instead, they are expected to be reduced to 9% in 2025, and by 2035 they should be no more than 7.5%. Similar ambitious plans have been developed by the government for heat losses. Today, heat is lost in over 20% of cases. The plan is to reduce heat losses by up to 13% by 2025, and in 2035, it is expected to reduce losses by up to 10%. Radical replacement of emergency networks is also provided - from 20% to 1% (Na chasi, 2017).

The main directions to implement the new energy policy of the state, laid down in the new Energy Strategy of Ukraine for the period up to 2035 "Security, energy efficiency, competitiveness", which was approved by the Cabinet of

Ministers of Ukraine on August 18, 2018 (EcoTown, n.a.). The key goals and priorities of this strategy include the role of the state in shaping a modern energy management system. These priorities include:

- “introduction of the public-private partnership system in the reserve of energy resources and the system of strategic reserves of energy resources;

- the removal of excessive restrictions in order to effectively and flexibly operate the energy infrastructure for the supply and transit of hydrocarbons;

- formation of main principles in the state sectoral policy based on the relationship of the state and the society, due to the principles of effective management, the delegation of powers and division of responsibilities ”.

Today, Ukraine is expanding the cooperation and use of the experience and practice of European countries to introduce renewable energy. Memoranda of cooperation were signed with Finland, Denmark, Slovenia, Slovakia. The UK's experience in developing renewable energy financing schemes is also positive. Given this and current European trends, it is necessary to emphasize the need for internal energy reforms. Such reforms should include the introduction of non-tariff forms of incentives for energy producers, deregulation in the field of leisure and regulatory work, and other steps aimed at improving the business climate (Dixigroup, n.a.).

Thus, it can be concluded that state support for innovative transformations in the energy sector is a key factor in ensuring the efficiency of such transformations. As the experience of most developed countries shows, comprehensive state support in the field of modern energy efficient technologies implementation at all stages of energy production, distribution and consumption is a basic prerequisite to reduce GDP energy intensity and to improve the energy security of the state. Ukraine also does not stand aside from the world of innovation in the energy sector. However, the level of state stimulation of such innovations in Ukraine remains rather low, which requires fundamental legislative changes in this direction, which should provide a high level of energy security in Ukraine.

CHAPTER 4 RE-DESIGNING ENERGY SECURITY STRATEGIES IN EUROPE

4.1 Energy security and the development of Smart Grid technologies

Since 2014, which has been characterized as relatively unstable year by the military and political events that have taken place in Ukraine, the issue of ensuring a stable energy policy is becoming increasingly relevant. Tense relations between Russia and Ukraine have threatened the transit of natural gas for the winter period 2014 - 2015. In this regard, the European Commission has published a strategy to provide European energy security, which envisaged the solution of short-, medium- and long-term prospects (AEVIS, 2014).

In the short term (until the winter of 2014), EU Member States considered conducting a stress test on the possibility of interruptions in energy supplies and, if necessary, setting up urgent measures to ensure reverse supplies between EU countries or switching to other fuels. Similar stress tests have been conducted in all 38 EU Member States and have provided the opportunity to simulate two scenarios related to power supply disruptions. The first scenario involved a complete halt to natural gas imports from Russia to the EU, the second scenario related to a disruption of gas imports along the Ukrainian transit route. As a result, the European Commission has argued that a market-based approach should be a fundamental principle with potential supply disruptions. In a competitive market, price signals can promote the new gas suppliers and thereby reduce demand from border neighbours.

Thus, stress tests were the first measure of energy security adopted in accordance with the European Energy Security Strategy (European Commission, 2014).

In the mid-term, the European Commission has proposed to reduce the demand for external energy consumption and to focus on the formation of the energy market, developing and implementing cross-border cooperation projects. In the long term, the European Commission proposes to focus on the development and production of internal energy resources, where renewable energy are given the highest priority (Gonda, 2015).

Energy security provision in the long term is of top-priority importance. Considering the supply security for the long term, there are several main areas (table 12).

Dependency on the import of fuel and energy resources indicates a degree of risk. Some EU Member States are focused on producing one type of fuel, but then they have to import another type. Ratios arising in the fuel and energy complex can be used by countries to diversify energy sources.

In recent years, the EU has managed to reduce imports of fossil fuels by saving energy and reorienting itself towards renewable energy sources, nevertheless, increasing the EU's import dependence in the near future is still an urgent task. Since domestic natural gas production in Europe, namely in the UK, is declining (Gonda, 2015).

Taking into account the energy security as an opportunity for national security and independence from external energy suppliers, European Union Member States observe the development of technologies (such as Smart Grid) for the generation and use of renewable energy sources, which are an alternative to electricity generation. In addition, a low-carbon development strategy should be considered and priority should be given to further development towards improving energy efficiency to enhance energy security.

TABLE 12. AREAS TO ENSURE THE SUPPLY SECURITY OF ENERGY RESOURCES TO EU COUNTRIES IN THE LONG-TERM

Areas	Description
Improving energy efficiency and meeting the 2030 climate targets	Prospective solutions should be oriented to reduce energy consumption by industrial installations, which account for 40% of all EU energy consumption. Housing consumers, who currently consume 25% of all energy in the EU, are encouraged to reduce energy consumption through smart technologies such as Smart Grid
Increased energy production and the need to diversify supplies and routes.	Development of renewable energy sources. Effective negotiations with major energy partners such as Russia, Norway and Saudi Arabia, as well as arrangements with new countries in the Caspian region for sustainable and secure fossil fuel supplies.
Completion of the Internal Energy Market (IEM)	Further improvement of RES in order quickly to respond to disruptions in energy supplies and redirection of energy through the EU to other regions of Europe where necessary.
The coherence of all EU Member States in foreign energy policy	EU Member States should inform the European Commission about planned agreements with other non-EU countries that may affect the security of EU energy supply.
Strengthening of emergency and solidarity mechanisms and protection of critical infrastructure	Increasing coordination and cooperation between EU countries to use existing strategic resource reserves, develop backflows, conduct risk assessments and ensure the security of planned energy supplies to the EU.

Sourse: Formed on the basis of European Commission (n.a.)

In this case (ETP Smart Grids, 2015; Tuballa et al., 2016), the use of the Smart Grids platform as an intelligent energy system allows to integrate the actions of all consumers and generate energy for efficient, sustainable and economically secure energy supply. Clever technologies make it possible to use renewable energy resources while increasing energy security and reducing independence from external energy supplies. Renewable energy makes it an important area of research thanks to its availability, reliability, and environmental friendliness, and in order to be used with smart technologies, Smart Grids provides order, proper condition and prospectivity in energy relations (Hossaina et al., 2016).

In this respect, the EU States make great investments in the development of renewable energy. Thus, during 2007-2017, renewable energy projects were developed in a positive vector, providing growth from 5.2% to 12.1%, share of electricity produced using wind, solar panels, waste, geothermal sources, sea waves and small hydro objects. Ultimately, according to 2017 results, the total volume of investments in RES in EU countries was 73.4%. In addition, investment is projected to increase to $ 7.8 trillion by 2040 (Frankfurt School-UNEP Centre/BNEF, 2018).

Thus, the development of renewable energy sources brings them to the foreground as one of the priority sources of energy supply. According to Eurostat statistics, the share of RES in the EU countries has been increasing rapidly since the 2000s, and in 2017 amounted to 17.53% of total final energy consumption (Fig. 5).

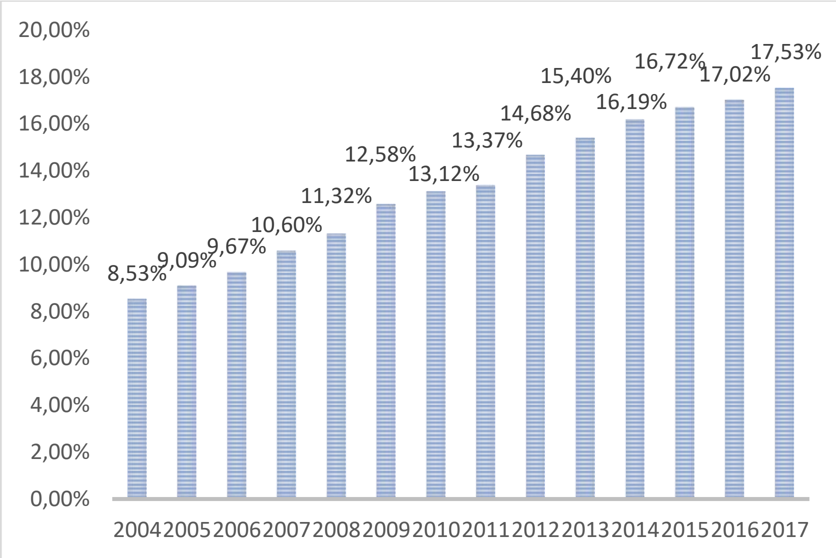


FIG. 5. THE SHARE OF RENEWABLE ENERGY RESOURCES IN EU COUNTRIES FOR 2004 TO 2017,% OF TOTAL ENERGY CONSUMPTION

Sourse: formed on the basis of data Eurostat (n.a.)

Technologies that generate energy from tides, oceans and waves provide a low percentage of energy production. Similarly, hydropower plants became the second after wind farms, and in 2017, were completely replaced by wind energy as one of the major sources of electricity generation from RES. Thus, a large part of the increase in the RES share in the total amount of consumed energy is due to new wind power.

In 2017, the amount of electricity produced by solar panels and wind farms in the EU States is 31.6 times and 3.5 times higher than in 2007. As a result, the share of wind and solar energy in the total electricity generated from renewables in 2017 increased to 37.2% and 12.3% respectively (Eurostat, 2019)

However, given the energy security regarding energy supply, the European Union intends to increase the share of renewable energy up to 20% by 2020, as provided for in national plans and directives adopted by the EU Member States. Moreover, some countries of the European Union have already reached the target of 20% share of energy consumption generated from renewable resources (Fig. 6).

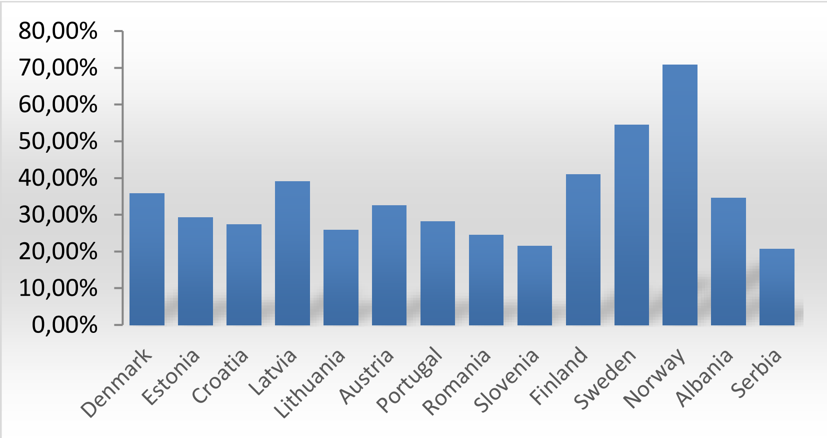


FIG. 6. LEADERS AMONG THE EUROPEAN COUNTRIES BY THE SHARE OF RENEWABLE ENERGY SOURCES IN 2017 IN % FROM THE TOTAL FINAL ENERGY CONSUMPTION

Sourse: formed on the basis of data (Eurostat, n.a.)

The highest values of RES share are observed in Norway, which is an independent state from the EU and produces 70.76% of total final energy consumption. High rates are caused by hydropower and wind power technologies. For example, over 300 dams have been built in Norway over the last 100 years, and there are new developments and significant technological potential that makes the country a world leader in hydropower development. In addition, thanks to its favourable geographical location and favourable climatic conditions, Norway is developing energy storage (World Economic Forum, 2019; The International Trade Administration, 2019).

The Swedish government's policy is oriented to achieve the set targets for renewable energy by a deadline earlier than the EU 2020 strategy. In 2017 the RES share is 54.5%. Given the large number of constructed wind turbines (3,681 turbines with a total capacity of 7,506 MW and an estimated annual production of 19.8 TWh at the end of 2018), as well as planned investments in new wind turbines, Sweden is planning to increase its renewable energy production 100% by 2040 (Swedish Institute, 2019; World Economic Forum, 2018; IEA, 2019). However, in order to increase renewable energy production by 100%, it is necessary to increase the annual production of RES by 10 TWh (World Economic Forum, 2018).

After Sweden, Finland and Latvia are among the leaders in renewable energy production, which account for 41.01% and 39.01% respectively of the share of energy produced from RES. Thus, Finland receives the largest amount of energy from hydropower plants and wind farms. By 2018, Finland has fully achieved the national commitments provided in the EU 2020 renewable energy strategies. In addition, more than 70% of energy production is emission-free, and by 2030 they will increase by more than 80% as the share of renewable energy (The International Trade Administration, 2019) grows.

According to recent research, Finland may be called the world leader in Smart Grid technologies, because in the early stages of renewable energy development, the related technologies such as remote reading, accurate power consumption measurements and real-time power failure monitoring were introduced. It caused the acquisition of more detailed information on energy use by consumers and billing in real-time. In addition, recently, with the development of smart grid technologies, Finland tries to meet the growing small-scale generation of energy accumulation at the level of electric vehicle users in order to control energy consumers' activities and to improve consumption efficiency (The International Trade Administration, 2019).

Thus, energy consumption in the European Union countries covers more than 30% of energy from RES, while China - 26%, and the United States, India, Japan - 18% (Enerdata, n.a.). With the help of advanced technologies, renewable energy, produced in the EU, has higher profitability and the power of produced sources continues to increase. However, due to price fluctuations in the traditional fuel market, the profitability of renewable energy sources may be changed. Against this background, the energy policies of the European Union countries continue to focus on the distribution and integration of renewable energy and Smart Grid technologies in local markets, which may be the most promising initiative in the future.

In addition, the development importance of renewable energy sources is driven by climate change and energy security issues due to the excessive consumption of fossil fuels.

4.2 Preconditions for energy security in the context of climate change

In view of the European Union countries’ intention to organize a single harmonized energy supply system, Member States should apply appropriate mechanisms for renewable energy sources development. As mentioned above, renewables are being developed to ensure energy security and reduce greenhouse gas emissions. Thus, in 2018, CO2 emissions amounted to 41.5 million tonnes, exceeding the value of emissions in 2017. The necessity to adopt the Paris Agreement within the framework of the United Nations Framework Convention on Climate Change is an important commitment according to which one provides the global average temperature growth well below 2 C (European Commission, n.d.).

According to recent research, the largest share of carbon dioxide emissions will come from vehicles and may vary depending on the type of transport. For example, cars account for more than 60% of Europe's total CO2 emissions from road transport. The least polluting types of transport are buses and motorcycles, which account for 11.90% and 1.20% respectively (Figure 7).

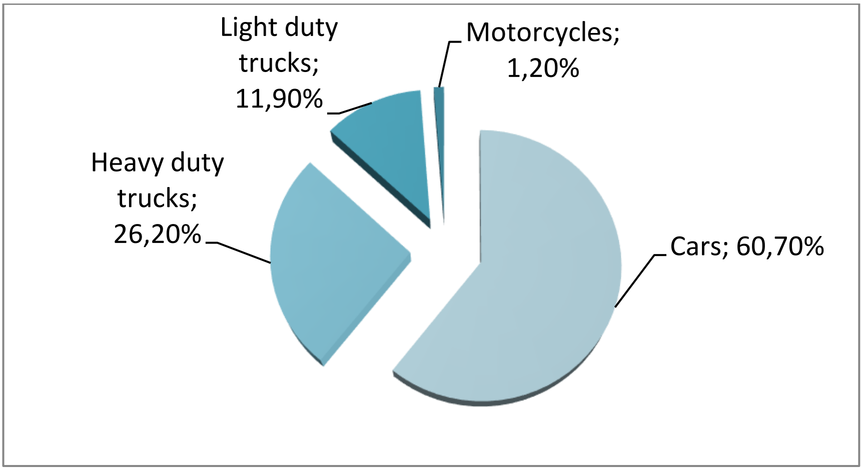


FIG. 7. CO_2 EMISSIONS OF VEHICLES IN THE EU MEMBER STATES

Sourse: European Parliament (2019)

In this regard, the European Union intends to introduce obligatory carbon dioxide emissions rates for trucks and buses. The draft EU directive is approved and obliges car producers significantly to reduce greenhouse gas emissions from trucks and buses. If the directive is successfully implemented, CO2 emissions from freight transport should be reduced by 15% by 2025 and 35% by 2030 (Reuters, 2018).

In addition, countries in the European Union, such as the United Kingdom, France, consider the ability to switch from gasoline engines to electric motors. UK, France, Netherlands intends to stop non-electric cars until 2040. And Norway (not part of the EU but geographically part of Northern Europe) sets more ambitious goals that mean stopping the sale of non-electric cars, by 2025.

It is commonly known from the International Energy Agency's (IEA, n.d.) annual publication, East Asian countries emit the largest amount of CO2 from fossil fuel combustion. China, as one of the world's largest sources of carbon dioxide emissions in 2017, emitted about 10.877 billion tonnes of CO2 (ASIATIMES, 2019). Other countries that also produce significant CO2 emissions include the United States, India, Saudi Arabia, Iran, Turkey, Iraq, and South Korea. One of the reasons for the increased emissions is the growth of oil consumption in the transport sector. Initially, in the North and South Americas, high carbon dioxide emissions were observed for a long time, but given the rapid growth of the automotive sector in Asian countries, CO2 emissions in both regions were equal. (IEA, n.d.).

In the EU, the amount of fuel used for road transport increased by 4%. In the US, coal use has actually declined, while fossil fuels, used in road trips, have increased by 1.4%.

Thus, in order to meet the commitments of Energy Strategy-2020 of the European Union and the Energy and Climate

Strategy-2030, certain steps are being taken to achieve the planned targets.

The German Center for Solar Energy and Hydrogen Research (ZSW) has released statistics regarding the sale of electric cars over the past 5 years, according to which there are more than 5 million cars around the world. The highest level of transport electrification was recorded in 2018 in China, where Tesla became a mass-produced vehicle and its Model 3 is sold better than other electric vehicles of all producers (Auto24, 2018; EIA, 2019).

Among the EU Member States, the leaders in the distribution of electric vehicles in 2018 are the United Kingdom, France, the Netherlands, Germany, Sweden, Switzerland, Spain (Fig. 8). Norway has produced the largest number of electric cars in 2018, making it the undisputed leader among European countries. East Asian countries (China, Japan, North Korea) have a total of 2.9 million units of electric vehicles, North America - 1.2 million units electric vehicles.

There are also examples of using and distributing electric vehicles in other countries. Since 2030 Israel plans to ban all gasoline and diesel cars and replace them completely with electric vehicles while reducing taxes and fees to zero. That is why the government is planning to finance the construction of another 2,000 new stations. As a result, around 177,000 electric vehicles are expected to hit the country's roads by 2025, and by 2030 their numbers will increase from less than 200,000 to 1.5 million units (BiznesCensor, 2018).

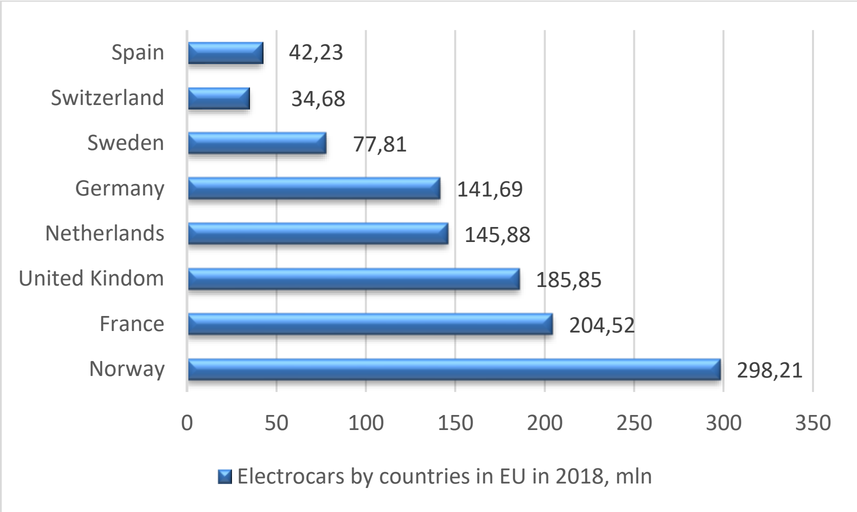


FIG. 8. ELECTRIC CARS IN THE EU MEMBER STATES AND IN NORWAY IN 2018, MLN

Sourse: formed on the basis of (Auto24, 2018; EIA, 2019)

In addition, many OECD countries have adopted a national policy to support sustainable development through clean technologies, the essence of which consists in energy security, competition in the market and environmental protection. The economic component of the policy is aimed at the development of renewable energy, which is generated on the basis of intelligent Smart Grid technologies with conventional fossil fuels will not be able to compete.

As a result of this policy, fossil fuel consumption in the OECD countries is expected to be around 14.0 million barrels per day by 2040, down 0.8 million barrels per day from 2010 (EIA, 2014).

Germany, which is a member of the European Union, is considered to be a leader in improving energy efficiency potential. Germany plans to increase renewable electricity by 65% by 2030 (World Energy Council, n.d.).

In addition, in 2014, Germany has already achieved one of its priority goals in the field of energy efficiency, namely to increase the renewable energy sources share in the overall fuel and energy balance by more than 10%.dia

Similarly, France is planning to reduce its fossil fuel consumption by 20% by 2020, on the way to improving efficiency and according to the EU directive. The French Government's policy also foresees a reduction in energy intensity by 2% annually by 2020 and by 2.5% by 2030, while paying attention to the transport sector. It is also the reason that the country has the highest number of electric trucks in 2018 compared to other EU countries. (Eurostat, 2019).

In addition to the above measures to spread electric cars in the EU Member States to reduce greenhouse gas emissions, the European Commission adopted a new sustainable energy alliance concept with a priority climate change policy in 2015. The Energy Union strategy consists of five interconnected and complementary components that provide great competitiveness for the energy market (Fig. 9). In this case, the purpose of the Energy Union was to provide sustainable and secure energy supplies to the European Union.

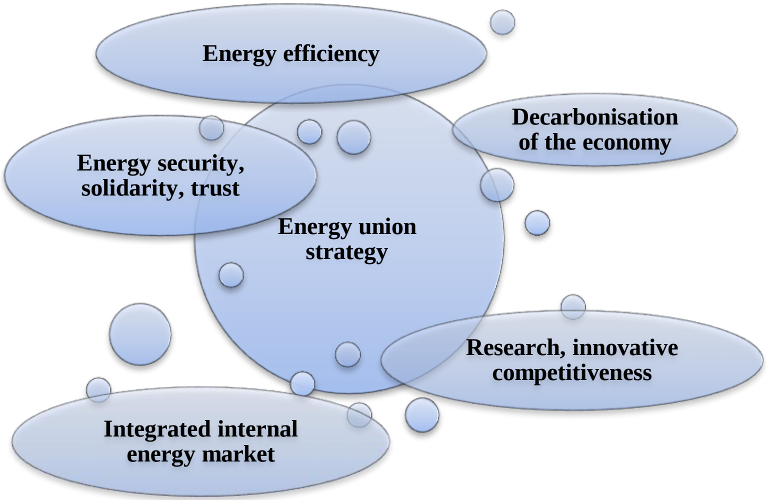


FIG. 9. MAIN COMPONENTS OF THE ENERGY UNION STRATEGY

Sourse: formed on the basis of (Eurostat, 2019; European Commission, n.d.)

According to the energy union components in Fig. 5, the EU countries should develop plans that focus on national, energy, and climate goals for the period from 2021 to 2030.

Each component of the Energy Union strategy has specific peculiarities and features that EU countries must take into account when forming energy security and climate plans. Certainly, *energy security, solidarity and trust* take into account the diversification of energy resources for EU countries, in order to widen the range of potential suppliers of resources and to reduce the risk of supply disruptions. In addition, this aspect is the efficient use of energy produced in EU countries. Another component of the strategy is *the integrated internal energy market*, which facilitates the free movement of energy across the European Union without any technical or regulatory barriers. The availability of a relevant market enables energy suppliers to compete with each other and to offer a reasonable price for energy resources.

Energy efficiency, as one of the important tasks and priorities for the EU, is to reduce demand, that is, to consume less energy (fossil fuels) in order to decrease environmental pollution and stabilize internal energy sources. In the long run, it will help reduce EU dependency on energy imports.

EU countries' desire for a global reduction of greenhouse gas emissions contributes to the decarbonisation of the economy. The proper intentions are supported by the Global Climate Change Treaties, initially under the Kyoto Protocol, as an additional document to the Framework Convention on Climate Change, signed in 1997, and then Paris Agreement, the Kyoto Treaty in 2015.

Research, innovations and competitiveness under the current conditions are important and promising, as they contribute to increased investment in clean technologies, the diffusion of new investigations in the development of renewable energy. Support for innovative projects should be achieved through coordination, research cooperation and further funding in cooperation with the private sector (Eurostat, 2019).

The importance to realize the EU's energy and climate goals on the basis of an energy union strategy must be achieved by 2030. It is important to note the coordination of actions between individual EU countries and the European Commission. It is necessary to take into account the fact that the different EU Member States may differently fulfil the objectives, that is related to the heterogeneous approach to energy security in each individual EU country.

Coordination of the Energy Union actions in the field of climate Regulation (EU) 2018/1999) is also a part of the program “Clean Energy for All Europeans”, which aims to:

1. the implementation of strategies and measures to support the objectives of the Energy Union, in particular, the EU energy and climate targets for 2030 and long-term agreements based on the Paris Agreement on greenhouse gas emissions;

2. promoting partnerships between the EU Member States to achieve the goals and objectives of the Energy Union Strategy

3. creating a favourable investment climate throughout the EU for the development of industrial infrastructure in order to create new jobs

4. improving the administrative mechanisms for monitoring the European Commission's commitments to streamline the EU's current energy security and climate change requirements, while respecting the principle of better regulation and planning;

5. ensuring consistent reporting by the EU Member States under the United Nations Framework Convention on Climate Change and the Paris Agreement, replacing the existing Energy Union monitoring and reporting system since 2021

Besides, observing the implementation of the Energy Union strategy, a national governance mechanism based on national, energy and climate plans (NECP) should be identified, as well as anticipating the development of other national strategies for the long term from 2021 to 2030. According to the transparency and accessibility principles, this management mechanism should be based on integrated reporting, monitoring and publication of data.

In view of the rules and governance mechanism of the Energy Union and Climate Strategy, EU countries are committed: first, to develop integrated national energy and climate plans that take into account all five components of the Energy Union strategy for the period from 2021 - 2030; second, to submit draft NECP plans at the end of each year for consideration by the European Commission; third, to inform about the goals achieved in the NECP draft plans. The European Commission will provide information on the state of the Energy Union strategy implementation through the annual report to assess the achievements of EU energy and climate plans (European Commission, 2019).

In 2018, the European Commission formed its strategic planning vision for energy and climate projects, which should be based on the competitiveness and decarbonisation of the economy by 2050. Thus, by the end of 2018, each EU country has submitted its projects under the NECP 2020 plans for evaluation by the European Commission. Following this, the European Commission, while making a global assessment of the cumulative impact of these projects, published the results, with further recommendations for improving their projects for each EU country. The final results should be published by the end of 2019 (European Commission, n.d.)

The climate targets (reduction of greenhouse gas emissions) and energy (reduction of dependence on energy imports from third countries, mainly from Russia), set by the European Commission, complement each other and ultimately lead to strengthening the energy security of EU countries (Gonda, 2015; Brown et al., 2008).

4.3 Institutional components of energy security in EU countries

From the point of view of institutional energy security of the European Union countries, since 2004, the European Neighbourhood Policy (ENP), aimed at establishing and setting close long-term relations with neighbouring countries, began to form. In addition, through close political, economic, social and cultural relationship, EU countries can participate in the security field. On the basis of the ENP, a common strategy for establishing a friendly relation of the border territories with the EU countries was formed. (Melnik et al., 2012).

However, since 2006, as a result of the conflict between Russia and neighbouring countries, energy supply disruptions have occurred in the EU. Russia hoped to achieve the goal fully to control the supply of natural gas from Central Asian countries. In addition, unresolved conflicts in Transnistria, Mountainous Karabakh and unresolved issues of South Ossetia and Abkhazia led to the August conflict in Georgia. Then in 2008, the European Union criticized Russia for its military action in Georgia, which went beyond self-defence. In addition, in winter of the same year, the European Union acted as an active intermediary in the period of the "gas war" between Russia and Ukraine (Yazkova, 2014).

Considering the fact that the EU imports more than half of all consumed energy, the dependency on crude oil imports is particularly high around 70% (EU imports, 2019). In this case, EU countries are highly dependent on the Russian Federation (Table 13). The table shows that the share of oil imports from Russia is 27.3%, which makes the EU countries most vulnerable in case of supply disruptions due to political, economic and other disagreements with Russia.

Thus, the above facts have become the most decisive impetus for the EU countries in the case of rethinking and adapting policies towards Russia and Eastern European neighbours. (Melnik et al., 2012).

In order to strengthen the European Neighbourhood Policy, the European Commission envisaged the adoption of new agreements and the formation of new ENP instruments, which was later reflected in the cooperation of six Eastern European partner countries: Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine. The countries together formed an alliance called the “Eastern Partnership”, formally approved at the EU General Summit in May 2009 (Yazkova, 2014). It envisaged the development of democratic values, economic integration (including the creation of free trade zones), mobility and migration, etc. (EU Neighbours portal, n.d.).

TABLE 13. IMPORT OF OIL PRODUCTS TO THE EU MEMBER STATES IN 2018

IN %

Partner-country	Value (Share %)	Net mass (Share %)
Russia	27.3	27.9
Norway	11.2	10.9
Nigeria	8.1	7.7
Kazakhstan	7.8	7.4
Iraq	6.9	7.5
Saudi Arabia	6.6	6.6
Libya	6.3	6.0
Azerbaijan	4.8	4.5
USA	4.4	4.2
Algeria	3.6	3.3
Iran	3.5	3.8
Mexico	1.7	2.2
Angola	1.3	1.3
Others	6.5	6.7

Sourse: Eurostat (2019)

Besides, the formation of cross-border areas that outlined the interests of the EU and partner countries on the European Neighbourhood Policy, was also provided. The most important topics were cooperation in the field of energy and energy security (reliable energy supply for partner countries and the EU, development of renewable energy), transport, development of the information society, health care, environmental quality improvement (reduction of greenhouse gas emissions), border regulation, migration and sea affairs. As an example, the achievement of these themes and intentions was to extend the Energy Cooperation Treaty for ENP countries that have adopted EU sectoral standards. At the same time, the European Commission has mandated the development of cooperation programs in the Eastern Partnership, the Member States of which have been given access to EU policy as observers. (Melnik et al. 2012).

Bilateral agreements, namely the Association Agreements, as well as the Association Agenda and Partnership Priorities and the directions of "Eastern Partnership 20" for 2020, serve as a common framework governing relations between the EU and its six Eastern Partnership partners, which are aligned with four key priorities, namely:

- a stronger economy (economic development and market opportunities);

- stronger governance (institutional development and governance);

- a stronger relationship (development of communications, energy efficiency, environment and climate change);

- a stronger society (mobility, migration and people-to-people contacts, including scientific cooperation) (European Commission, n.d.; European Commission DG NEAR, n.d.).

The above priorities have been adopted at the "Eastern Partnership Summit" held in Brussels in November 2017 and, in the opinion of the European Commission, are the results in support of a systematic and results-oriented approach to the

Eastern Partnership countries (European Commission DG NEAR, n.d.).

In order to provide a more streamlined approach, new global policy priorities are foreseen, as set out in the United Nations Framework Programs for the period 2018-2020, among which there is the "Sustainable Development Agenda 2030" (United Nations, 2016) and the Paris Climate Agreement (United Nations, 2015; European Commission, n.d.).

It should also be noted that in the institutional aspect, the steps towards the further final stage to form the internal energy market for electricity and natural gas were presented as the formation of the European Regular Energy Authorities. Thus, on the basis of Regulation (EC) No 713/2009 of the European Parliament and of the European Council of 13 July 2009 (European Parliament et al., 2009) regarding an Agency for the Cooperation of Energy Regulators formation, an Agency for the Cooperation of Regular Bodies for Energy was organized (Breach et al., 2013).

Being independent of economic operators, electricity and gas producers, transmission and distribution system operators, the Agency promotes cooperation between national regulatory authorities in order to achieve market integration and harmonization of the regulatory framework within the tasks and objectives of the EU's energy policy (Agency, n.d.; Melnyk et al., 2012).

A great deal of attention from the Agency is directed to:

• creating a more competitive and integrated market for consumers, while promoting the diversification of energy supply;

• improving the efficiency of energy infrastructure, while guaranteeing the free movement and transport of new energy across borders in order to improve the security of supply for EU consumers and businesses;

• forming a controlled and transparent energy market, while guaranteeing fair and reasonably priced energy and natural gas prices to consumers. (ACER, n.d.);

• forming access to renewable electricity networks, while increasing the energy efficiency of fuel and energy resources (Melnyk et al., 2012).

• developing guidance for national energy regulatory authorities, transmission system operators and EU institutions, while monitoring regional cooperation between energy system operators (ACER, 2016).

It is important to note that during the stimulating process of the diversification of energy supplies and the ways for their transportation, the European Union has taken all the necessary steps to eliminate possible contradictions in national legislation and to coordinate the activities of national regular authorities in the electricity and natural gas markets in EU countries. That is why the Third Energy Package (2009) was created, which aims to provide opportunities for all European consumers to take advantage of a competitive energy market (free choice by energy suppliers and security of supply, more competitive prices) (Melnyk et al., 2012). In this case, efficient competitive energy markets are becoming increasingly relevant (IEA, 2017).

The competitive markets that give consumers the freedom to choose their energy supplier, which has a positive effect on increasing competition, improving the quality of provided services, and facilitating the introduction of modern technologies (Ukrenergo NPC, 2017).

CHAPTER 5 EUROPEAN ENERGY STRATEGIES FOR SMART CITIES

5.1 Peculiarities of Smart Grid Project Formation in the Context of Smart City International Consortia Implementation

Today, in the context of building future smart cities, the ideas of smart grid implementation are effectively implemented. Smart Energy is one of the key components of Smart City. In turn, it should be noted that efficient energy consumption in the country determines the degree of its environmentally sustainable development. In this context, it is appropriate to investigate the development of energy efficiency strategies in the context of the Smart City International Consortia implementation.

Under conditions of social and economic transformations, characterized by a change in the geographical distribution of the population (the number of population in cities exceeds the population outside their borders), the development and implementation of comprehensive plans for efficient resource allocation (including energy) are necessary to increase the level of anthropogenic and man-made load, energy consumption, environmental protection and even overcrowding. In order to solve these issues, the concept of "smart city", which is a key strategy to fight poverty and inequality, unemployment and to create an effective energy efficiency system, was created (Bergen Kommune, n.d.).

According to Eurostat, "a smart city is a city where traditional systems work more efficiently through the use of information and communication technologies" (Eurostat, n.d.). Smart City also refers to the "holistic concept of smart integration of information and communication technologies for monitoring and managing urban infrastructure" (Shost, 2018).

According to the studies of the consulting agency Navigant Research, Smart City includes the following key components: Smart Energy, Smart Water, Smart Buildings, Smart Transportation, Smart Government.

According to the Official website of the European Union, the concept of smart cities is based on the following elements:

- "smart economy". It is specified to increase labour productivity through the implementation of e-business and commerce and the use of innovative technologies in the production of goods and provision of services;

- “smart mobility”. It can be provided by the formation of transport and logistics systems based on information and communication technologies, which, in turn, allowed the use of different transport modes in any locality;

- "smart labour potential". This component of the smart city is the necessity to develop electronic skills, creativity and stimulate innovative breakthroughs, as well as to increase the level of education and skills in the city's labour resources;

- "smart life". This component implies the formation of such a model of people's way of life, which is aimed at improving their health and cultural development;

- “smart state and local government”. This component involves the provision of interactive local governance that is able to ensure the effective inclusive functioning of the city;

- "smart environment". In this component, in accordance with the concept of smart cities construction, particular attention is paid to the principles of energy efficiency in the context of greenhouse gas emission reductions. It is within the framework of the subsystem "smart environment" that the creation of "smart energy" based on the introduction of systems for monitoring and control of the air pollution level, closed energy networks, restoration and construction of buildings, improving energy efficiency etc.

The European Union is one of the main initiators to redevelop usual cities into "smart cities".

Thus, € 450 million has been earmarked for the construction of “smart cities” by the European Union in the period 2011-2015. The main areas of improvement and modernization at the expense of these funds were: smart energy management, improving the energy efficiency of buildings and transportation systems, the introduction of information and communication systems in all areas of service, etc. (Pobochenko et al. 2016).

There are "smart cities" in every country of the European Union, but most are in Germany, the United Kingdom, Italy and Spain.

Such countries as Austria, Denmark, Estonia, Italy, Norway, Slovenia, Sweden have the highest share of “smart cities” in terms of volume of all cities.

According to Eurostat, the most successful “smart cities” of the European Union are Amsterdam, Barcelona, Berlin, Vienna, Copenhagen, Stockholm, London, Munich, Paris, Frankfurt (Eurostat, n.d.).

It should be noted that Juniper Research, together with Intel, annually produces ratings of “smart” cities in the world.

These ratings are based on the evaluation of cities by the following parameters: mobility of urban transport, quality of health care, level of public safety, level of labour productivity.

According to Juniper Research and Intel, Singapore is the world's smartest city in 2017 (Table 14). It leads the top 20 "smart cities" in the world, ahead of London, New York, San Francisco, Chicago and Seoul, including in the overall ranking. (Juniper Research, n.d.).

TABLE 14. TOP-20 “SMART CITIES” OF THE WORLD

Rating of “smart” cities of the world	City	Region
1	**Singapore**	**Asia Pacific**
2	**London**	**West Europe**
3	**New York**	**North America**
4	**San Francisco**	**North America**
5	**Chicago**	**North America**
6	Seoul	Asia Pacific
7	Berlin	West Europe
8	Tokyo	Far East & China
9	Barcelona	West Europe
10	Melbourne	Asia Pacific
11	Dubai	Middle East & Africa
12	Portland	North America
13	Nice	West Europe
14	San Diego	North America
15	Rio de Janeiro	Latin America
16	Mexico City	Latin America
17	Wuxi	Far East & China
18	Yinchuan	Far East & China
19	Bhubaneswar	Indian Subcontinent
20	Hangzhou	Far East & China

Source: Juniper Research (n.d.)

The top five Smart Cities in the world in 2017 include Singapore, London, New York, San Francisco, Chicago and Seoul, and it is reasonable briefly to observe projects and programs of them.

Smart Nation information technology project has been implemented in Singapore. The main advantages of the project are complete city automation, a progressive field of medicine and control of all spheres of life.

London took second place in the Smart Cities Rankings and is positioned as a centre for the development of talent in the digital and innovation services sectors. In addition, London is considered one of the best cities in terms of the convenience of doing business. In turn, the benefits of implementing “smart city” measures include the following: efficient use of alternative energy sources, modernization of the outdated subway system, and reduction of population costs.

The strategy for a "smart city" deployment in New York was focused on shaping the status of one of the safest cities in the United States. In today's environment, the streets of the city are filled with CCTV cameras and sound sensors that instantly respond to the sounds of shots and send a signal to police. In addition to focusing on city safety, special attention was paid to innovative and technical aspects: Vonage's initiative was to set up interactive booths with the purpose to communicate with city services, to provide use of i-pad and to charge a phone, and connect to the Internet. Innovative technologies have also been introduced in the context of the medical platform implementation that provides for the systematization and collection of data from patients' devices, such as "reasonable scales", fitness bracelets, etc. Data from such devices help make a more accurate diagnosis.

In San Francisco, innovative technologies are focused on solving environmental issues. The government stimulates the development of alternative energy. Thus, the city has the world's most developed electric vehicle refuelling network. About 80% of San Francisco's urban waste is recycled. In order to care about the population, special applications have been created for the comfort of pedestrians with hearing or visual impairments.

The concept of forming a "smart city" in Chicago involves the implementation of the Array of Things program. The purpose of this program is to connect all the city's electronic devices into a single network. In particular, Chicago is considered a city of "green roofs", the area of which today occupies more than 500,000 square meters. The aim of such greening is to reduce carbon dioxide levels in the city and to create a beneficial climate.

Today, developing countries are realizing the full benefits of smart cities. These benefits are reflected in the social, environmental and economic spheres. In this regard, Juniper Research and Intel's smart cities ranking, which is annually updated, has new cities and regions and changes leaders. That is why in our opinion, it is advisable to consider strategies and projects aimed at providing smart energy technologies implemented by countries on the way to the formation of a successful Smart City.

One of the most successful pilot projects is PowerMatching City, which began in 2007 in Hugkerk (Groningen, Netherlands). The purpose of the project is to find practical solutions to the problems related to the transition to sustainable energy supply.

In the course of the project, 40 residential buildings were equipped with solar panels, innovative heating installations, and intelligent household appliances.

In the course of the pilot project, consortium partners and residents jointly established two energy management services to promote flexibility in energy supply: the Smart Cost Savings Service allowed experiment participants to minimize energy consumption and production costs, and Shared Energy Sustainability assistance to the inhabitants of forming a sustainable society.

In 2013, the project entered the top 100 largest projects in the world, which are the most stable. ICT is one of the founders of the project, which is responsible for creating an IT infrastructure that reads smart meters, manages equipment, purchases, stores and processes data, and develops a tablet application, and helps residents gain insight into manufacturing and energy consumption and operation of your smart equipment.

The consortium consists of DNVGL, Gasunie, Enexis, Essent, ICT, TNO, as well as research partners: TUD, TUE and Hanzehogeschool Groningen (ICT Group, n.d.).

It should also be noted that the consumers' response to the project creation was positive.

The evaluation results of the operation of the micro-combined heat and power (micro-CHP) systems, hybrid heat pumps and electric vehicle charging stations indicate that the system is responsive to changing requirements and maintains an adequate level of energy supply for each family in the long run.

It should also be noted that the consumer has a positive response to the project.

The PowerMatching City project is successful because it demonstrated the technical implementation of the smart energy networks idea and the economic feasibility of flexible energy supply (Flexiblepower Alliance Network, 2015).

The Smart Grid City Boulder project, which is the first city where the Smart Cities concept based on innovative Smart Grid energy-saving technologies was launched, deserves special attention.

In December 2007, the integrated energy company Xcel Energy, USA, which serves the state of Colorado, established a Consortium of Smart Networks, bringing together leading technology, engineering firms, industry leaders and IT experts (Neville, 2008).

The following key components of the Smart City have been identified for the project within the consortium:

- dynamic system with a high share of use;

- information technology;

- a high-speed two-way communication system in real-time;

- sensors all over the network, allowing you quickly to diagnose and adjust;

- data, required for decision making and support of the system during peak periods;

- distributed generation technologies (wind generators, solar panels and rechargeable electric vehicles);

- automated "intelligent substations"

- home electric power controls;

- automated energy consumption in homes.

The following planned activities of the pilot project were implemented in 2009:

- 45,000 customers were equipped with smart metering devices;

- the program of substation modernization, distribution and communication system is implemented by 45%;

- more than 100 miles of optical fibre is routed;

- 15,000 of 25,000 double-sided meters have been installed;

- installation of home electricity management has been started;

In 2010, preparatory work on the pilot launch of new tariffs was carried out.

The main benefits and effects of implementing a smart Boulder project are:

- stability (reliable power supply and maintenance);

- energy saving (reduction of fuel consumption);

- comfort and convenience;

- cost (reduction of payment for electricity);

- cash settlement (monetary expression of electricity production);

- improvement (use of the latest and best technologies);

- society (unions to introduce changes);

- choice (the choice of sources of electricity).

The prerequisites for the implementation of the Smart Grid, Smart City project in Australia were the following problems that needed to be solved:

- The Australian grid is being developed, and outdated energy demand and generation approaches used for grid design are in doubt;

- total electricity demand and consumption has moved from positive growth in the past to a general downward trend;

- distributed generation technologies (such as solar photovoltaic systems) are increasingly in demand among consumers;

- regulatory frameworks, policies and standards, which should be taken into account, are changed over time.

The above problems have led to the need to create a more advanced, sensitive network that incorporates innovative technologies and increases the decision-making power of network operators. This, in turn, has led to the development of smart grid technologies (Goldsmith, 2014).

The Smart Grid, Smart City project was initiated and funded by a number of government and industry bodies. The government has allocated $ 100 million to the federal budget for 2009-2010. In addition, about $ 400 million was provided by Ausgrid, EnergyAustralia and consortium partners, including IBM Australia, GE Energy Australia, Grid Net, CSIRO, TransGrid, Landis + Gyr, Sydney Water, Hunter Water, Newcastle University, University of Sydney, Local Area Lake Macquarie City Council and Newcastle City.

The following project objectives were identified:

- to develop an information base on technologies of the intellectual network;

- to develop public and corporate awareness of economic and environmental benefits from the introduction of smart grids;

- to gather reliable information and data to familiarize the wider industry with the features of intelligent networking in Australia.

- to explore synergies with other infrastructure (for example, gas, water and the National Broadband Network).

In general, Smart Grid, Smart City surveys are aimed at delivering results that could be used to determine whether individual or combination of smart grid technologies can be used to achieve economic benefits for Australian electricity consumers.

In the course of the project, a number of smart "grid" and "customer-oriented" technological systems were developed and tested in the Ausgrid network and EnergyAustralia's retail business in New South Wales.

About 17,000 electricity consumers were involved in the research. The research has been aimed at identifying how Australian consumers perceive and respond to the capabilities of smart grid technology.

The practical interest is the choice of test areas for implementation of the project.

The study has largely taken place in big areas of Newcastle and Sydney. The Smart Grid, Smart City location was chosen to represent different variations of geographic, climatic, demographic, and electrical characteristics across Australia to produce results that would be relevant nationally.

Test locations include a combination of both urban and regional territories.

The test locations demonstrate Australia's energy consumption patterns, reflecting energy demand peaks including summer and winter. In turn, the test locations had sufficient variability of topographic and relief features, which allowed for accurate testing of alternative technologies. Based on the selected territories, different configurations of terrestrial and underground networks were presented. The test territories contained areas with a high level of network utilization, which identified them as good places for energy efficiency and demand management initiatives.

The following main advantages and effects of the Smart Grid, Smart City project are identified:

- development of technologies and the introduction of the smart grid;

- the introduction of smart grid technologies in Australia has the potential to generate economic benefits of up to $ 28 billion over the next 20 years;

- implementation of tariffs, including dynamic tariffs that reflect the cost of electricity;

- changing consumer behaviour on energy consumption (to better manage peak demand growth in the future).

- reform of the energy market.

- reduction of capital investment (through better management of peak demand).

The Energy Smart Miami project deserves special attention too. The project is being implemented in the US in Miami, Florida. Participants in the project are Florida Power & Light, General Electric, Cisco Systems and Silver Spring Networks. Investment contributions to the project amounted to $ 200 million. The benefits of the project are the introduction of smart metering systems for end consumers and the transition to automatic regulation of energy consumption. At the same time, smart metering systems can be made available to more than millions of Miami households and businesses (Ukrenergo NPC, 2018).

Smart Islands Projects and Strategies (Friedrich-Ebert-Stiftung, 2016) are quite interesting in the context of energy efficiency.

The Smart Islands Initiative is an effort by local government representatives to make effective use of the islands' potential to create laboratories that will function to develop social, economic and political innovations.

The Smart Islands initiative aims to demonstrate that islands can carry out pilot projects, generate knowledge of smart and efficient management resources and infrastructure that can then be deployed in other areas (in mountainous, rural and generally geographically separated regions).

The project received special support from KEDE, the Central Union of Municipalities of Greece. Annually KEDE organizes forums to share knowledge and experience on developing smart projects and strategies at the local level.

The Smart Islands initiative forms a series of activities, among which the Pact of the Islands is of particular importance. The Covenant of Islands is a political strategy to engage the islands beyond the EU's 2020 climate and energy goals.

Defining the island as smart is linked to its ability to implement integrated infrastructure and natural resource management solutions, namely energy, transport and mobility, waste and water, as well as to promote innovative and socially inclusive management and financing methods.

The introduction of the innovative technologies in combination with environmental management, which preserves landscape protection and the rational use of coastal and marine resources, is a key aspect to provide sustainable economic activity.

In light of the increasing trend towards a new type of energy market, new business models for energy supply are emerging, enabling consumers to control their energy consumption, to use innovative technologies (smart meters, electric vehicles, etc.). In this direction, the islands are ideal territories for testing new scalable technologies and processes with the participation of all relevant actors, namely government bodies, utility companies and networks of operators, market participants and citizens.

Iceland's potential for today is determined by the strategy of transformation into smart territories in the context of sustainable development.

Iceland has created the conditions for the formation of two EU-wide projects, ISLEPACT and SMILEGOV, facilitating islands cooperation in the field of local energy planning and the implementation of a sustainable energy project.

The first forum ”Smart Islands” in cooperation with the Friedrich Ebert Fund was organized by:

- The DAFNI Network of Sustainable Aegean and Ionian Islands;
- The Aegean Energy Agency, a non-profit organization providing scientific services and technical advice to the DAFNI network;
- KEDE, the Central Union of Municipalities of Greece;
- FEDARENE, the main European network of regional and local organizations responsible for implementing, coordinating and supporting energy and environmental policies at regional and local levels.

The experience of foreign countries in the development of "smart cities" shows that investment in the development of information technology over several years will pay off, and in the future, the city receives significant profits from the savings of resources and benefits in the social and environmental spheres. At the same time, an important aspect is the ability of the authorities to assess and to analyze the city's potential and to make smart decisions. After all, the city is becoming intelligent in the process of acquiring new innovative technologies, approaches and management methods aimed at environmentally sustainable development.

Based on the generalization of literature sources, we have formed some recommendations for the implementation of

Smart City systems in the context of implementing energy strategies:

- involvement of all stakeholders in the process of energy-efficient technologies formation;
- development of public and corporate awareness of economic and environmental benefits from the introduction of smart grids;
- formation of a stimulation and motivation mechanism of organizations implementing innovations in the field of innovative technologies for the city’s effective functioning;
- development of information base on technologies of the intellectual network;
- gathering reliable information and data to know about the broader industry with the features of the smart grids using in the city;
- development of the new advanced automated systems;
- creation of innovative laboratories in order to stimulate new developments aimed at preserving the ecosystem and improving the citizens’ comfort and safety and the city as a whole;
- exploring synergies with other infrastructure (e.g gas, water, etc.);
- data security;
- involvement of state and local government bodies in the implementation of "smart city" systems;
- creation of a coordinating body for the implementation of innovative technologies in the city.

5.2 The Global Smart Grid projects implementation experience

In most developed countries, most attention is given to the introduction of "intelligent" technologies in electricity as a basis for environmentally sustainable development.

There are various interpretations of the Smart Grid concept in the global energy industry. Based on the generalization of scientific and literary sources, we have outlined the most common approaches to defining the concept of Smart Grid, presented in Table. 15.

An analysis of existing approaches to defining the essence of Smart Grid enables us to draw the following conclusions. In different publications, the concept is interpreted differently, defining the views and positions of the parties involved in the development of this area in accordance with their development strategies, interests, programs and goals that they follow.

According to Zpryme Research & Consulting in 2010, China is the leader in Smart Grid technology (with $ 7.32 billion in investment). The second place goes to the USA, which financed "smart" networks for $ 7.09 billion. Also, the five countries with the highest size of investments are Japan (investing $ 849 million), South Korea (investing $ 824 million) and Spain (with $ 807 million invested in the future of energy). Figure 10 shows 10 countries by the rate of investment in Smart Grid technology (Ecology Life, 2011).

According to experts of Zpryme Research & Consulting (Regional Branch of the National Institute for Strategic Studies in Dnipro, 2011), investments into the global market of smart grids by 2030 will amount to $ 2 trillion.

According to a European Commission report on "Smart Grid projects in Europe: lessons learned and current developments" published in June 2011, investment in smart grid projects will amount to € 56.5 billion in the EU by 2020; in the US - from € 38 to 334,5 billion by 2030; in China, more than € 70 billion by 2020.

TABLE 15. APPROACHES TO DETERMINE THE CONCEPT SMART GRID

№	Determination, author/source	Essence
1	Smart Grid	it is an electric grid that, on the basis of modern innovative technologies of equipment, effectively coordinates and manages the operation of all its connected objects - from various systems of generation, transmission and distribution of electricity to its consumers in order to create economically profitable and stable energy system with low losses and high level of the reliability and quality of energy supply (Ukrenergo NPC, 2018)
2	Smart Grid, IEEE - The Institute of Electrical and Electronics Engineers	electrical networks that meet the requirements of the energy-efficient and economical operation of the grid through coordinated management through modern two-way switching between substations that accumulate sources and consumers (Office of Electricity U.S. Department of Energy, n.d.)
3	Smart Grid, Ministry of Energy USA	a fully automated power system that provides a two-way flow of electricity and information between power stations and devices everywhere. Smart Grid fills the power industry with "knowledge" that allows dramatically to increase the efficiency of the energy system by applying the latest technologies, tools and methods (United States Department of Energy Office of Electric Transmission and Distribution, 2003)
4	Smart Grid	these are "electricity grids that meet the requirements of energy-efficient and economical operation of the grid through coordinated management through modern two-way communications between elements of grids, power plants and electricity consumers" (ETP SmartGrids, 2006)
5	Smart Grid,	ideology of national electricity development programs (State structures in most countries)
	Smart Grid	Perspective base to optimize business (countries-producers of equipment and technologies)
	Smart Grid, Energy companies	the basis for ensuring sustainable innovative modernization of its activities (Cheremisin et al., 2015)
6	Smart Grid	set of organizational changes, the new model of processes, decisions in the field of information technologies, as well as decisions in the field of automated systems of process control and dispatching control in the power industry (NETL, 2007)
7	Smart Grid	is an electrical grid which includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy-efficient resources (United States Federal Energy Regulatory Commission, 2008)
8	Smart Grid	is an electricity system incorporating electricity and communications networks, which can intelligently integrate the actions of parties connected to it (Utilitymagazine, 2014)
9	Smart Grid	is defined as the electrical distribution technology that uses computer-based remote control and automation to improve the delivery efficiency of electricity (Faizan, 2019)

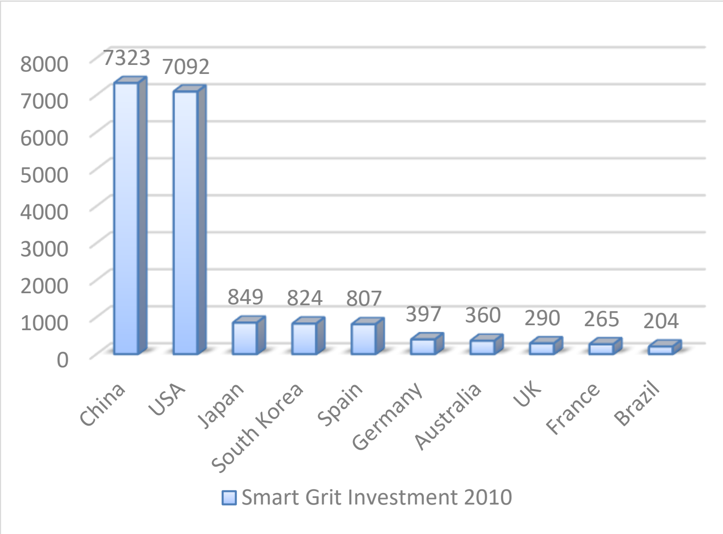


FIG. 10. RATE OF INVESTMENT IN THE SMART GRID TECHNOLOGIES IN 2010

Source: Regional Branch of the National Institute for Strategic Studies in Dnipro (2011)

According to the International Energy Agency, the global investment required for global energy development by 2030 will be about $ 16 trillion. Including over $ 2 trillion. on the development of "intelligent" networks (Ukrenergo NPC, 2018).

The existence of a society in harmony with the environment and economic growth can be achieved through the implementation of "smart" electric grids.

Today, in all countries of the world, the implementation of projects with "smart" electric grids is becoming more and more urgent.

The implementation of projects with "smart" electric grids reflects the development of innovative technologies in the city, the level of electricity use in transport infrastructure, the level of latest technologies perception by the population (Cheremisin et al. 2015).

In this regard, we have explored the following large-scale projects in the context of implementing smart grids: ADDRESS (Italy), Telegestore (Italy), CRISP (Critical Infrastructures for Sustainable Energy Systems), FENIX Project (Flexible Electricity Networks to Integrate the Expected Energy Evolution) and others.

It should be noted that Italy is actively encouraging the growth of electricity from renewable sources. Renewable energy sources cover 32% of Italy's national energy production.

In order to promote the evolution of electricity grids, the introduction of "smart grids" is essential for improving energy efficiency, sustainability and security in the country.

Italy's key user in the area of smart grids is ENEL.

ENEL Distribuzione participates in numerous smart grid projects, including Electric Mobility and Interactive Energy ADDRESS, a large-scale project co-funded by the European Commission to ensure the active participation of small and commercial consumers in the energy market (Bevini, 2018).

The aim of the project is to create a future electricity grid - flexible, publicly available, reliable and cost-effective with the possibility of small and commercial consumers' active participation.

The project was valid for five years (from June 1, 2008, to 2013).

The ADDRESS project was implemented by a consortium of 25 partners from 11 European countries that were carefully selected to meet the needs of the project in terms of skills, competencies and understanding of problems and possible solutions (Towards the smart grids of the future).

In particular, participants include:

- Manchester Research University, Universidad Pontificia Comillas, University of Siena, Universita di Cassino, ENEL Produzione, VTT, VITO, Fundacion Labein, KEMA, Consentec;

- suppliers of electricity and power supply companies (EDF-SA, ENEL Distributie Dobrogea);

- producers of electrical equipment (ABB, Landis + Gyr, ZIV);

- producers of electrical devices and consultants (Philips, Electrolux, RLtec);

- operators of distribution and transmission system (ENEL Distribuzione, EDF Energy, Iberdrola Distribucion Electric, Vattenfall);

- information and communication technology (ICT) providers and producers of electrical equipment (Ericsson Espana, Alcatel, Current).

The total budget of the project was 16 million EUR, which was funded by the European Commission.

Key participants in the field of smart grid formation in Italy include AEEGSI, an independent body that regulates, controls and coordinates the electricity, gas and water markets; TERNA, the national transmission system operator, regulated by AEEGSI. TERNA has more than 98% of transmission networks and is responsible for the design, operation and maintenance of the transmission system. TERNA has also developed the Smart Islands project, which consists of a strategy for a modern, smart, innovative and high-tech future for islands that are not connected to the national grid.

One of the most unique projects in the world, also implemented in Italy, is the Telegestore project.

The essence of the project was to create an additional regulating network for 30 million consumers, which controls peak demand and improves the efficiency of work with unfair payers.

The TELEGESTORE system consists of three main parts: the remote metering system, the subscriber management system and the potential system of providing additional paid services.

The total investment in the project amounted to 2.1 million EUR.

Features of the TELEGESTORE project are:

- measurement of active and reactive energy;

- AMR functions;

- remote connection / disconnection for load control;

- functions of fraud detection / prevention

- informing consumers;

- possibility of prepayment (without card);

- management of energy demand;

- monitoring the level of individual customer service quality;

- the potential ability of additional offers which are paid (Smart Energy International, 2004).

The implementation of the TELEGESTORE project has several advantages for both company ENEL and its customers, as well as for the whole of Italy's power grid, Fig. 11.

Thus, on the basis of the project implementation, consumers received a higher level of services including the efficiency of distribution, sales and accounting, as well as the possibility to use differentiated, i.e lower tariffs.

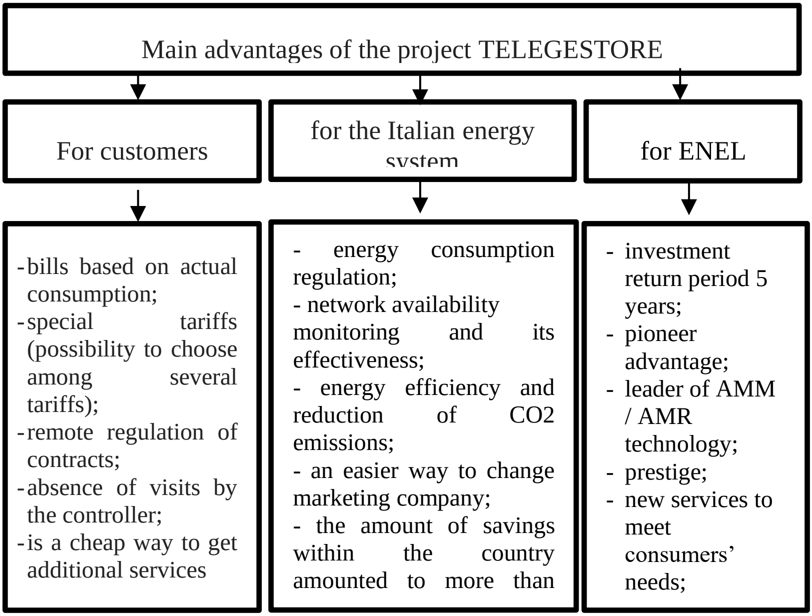


FIG .11. MAIN ADVANTAGES OF THE TELEGESTORE IMPLEMENTATION FOR CUSTOMERS, THE ELECTRIC POWER SYSTEM OF ITALY AND ENEL
Source: Smart Energy International (2004)

Enel's remote accounting system has become the benchmark in the world, with which all similar projects are compared. It is one of the most interesting, ambitious and innovative industrial projects in the last few years in the electricity business. Enel is currently expanding its system to other countries. Representatives of more than 80 energy companies in the world have already been interested in TELEGESTORE.

It is also reasonable to consider the features of the project "The Critical Infrastructures for Sustainable Power" (CRISP) implementation.

The objective of the project “Critical Infrastructures for Sustainable Energy Systems” (CRISP) is to investigate the support of large-scale power grids and renewable energy systems with information and communication technologies.

The project involves three European countries, namely Sweden, France and the Netherlands. The Consortium is headed by the Netherlands Energy Research Center. Additional partners include Inventer la Distribution de l'Electricite de l'Avenir (IDEA), EnerSearch AB, Eon Sverige AB, Blekinge Institute of Technology and ABB Automation Technology Products AB.

The project was started on October 1, 2002. It was completed on June 30, 2006.

The total budget of the project was EUR 3 150 251, the EU contribution was EUR 630 468.

The activities of CRISP was to implement the following steps:

1. Scenarios and strategies for highly redistributed power grids and information and communication technologies (the stage involves developing strategies to increase the ability of networks to continue to function during failures).

2. Implementation of distributed intelligent information and communication technologies projects and tools for energy use (at this stage requirements for information and communication technologies, technical features, modelling tools and experimental software for scenario and strategy formation were developed).

3. Distribution and application

4. Activation, experiments and tests

5. Project management

The main results from the implementation of the CRISP project are the new architecture of the distributed energy grid has been described; the models for strategies implementing information and communication technologies, in which various operational situations have been studied; modelling tools have been created; experiments and tests in different countries have been carried out.

The CRISP project has the opportunity to provide practical guidance on the use of smart information and communication technologies to optimize high-redistributed generation (CRISP) power grids (CORDIS, 2005).

In January 2009, the E-DeMa project was launched. Germany was the country that actively participated in the project. In particular, the project participants were German companies RWE Energy AG, Siemens AG, Miele & Cie. KG, Stadtwerke Krefeld AG and Prosyst Software GmbH. (European Commission JRC Smart Electricity Systems and Interoperability, 2019).

The aim of the EDeMa project is to achieve greater energy benefits and efficiency gains for power generators, utility companies, device manufacturers and, above all, customers.

The project E-DeMa aims to develop and to demonstrate decentralized integrated energy systems for the E-Energy market of the future.

The project activity is extended to both rural and urban areas with two different distributed networks.

The main objective of the project is to combine electricity generation and information and communication technology to create an "energy information centre".

One of the main aspects of the project is the design and development of integrated information and communication technologies - interconnection, which is part of a distributed subsystem of consumers that read data and regulate (program) "smart" meters that process "price signals" from suppliers. Based on such "price signals", consumers can switch their consumption to low load hours, thus benefiting from lower tariffs. Consumers can also generate electricity and send excess electricity to distribution networks, gaining access to the new offered services.

The project was completed in December 2014.

The main objectives of the project FENIX (Flexible Electricity Networks to Integrate the Expected Energy Evolution) are to work out mechanisms for the operation of a pan-European energy system; to develop algorithms for inclusion in the common system of generation distributed sources and renewable energy sources; to demonstrate developments at landfills in Spain and the United Kingdom. The project brought together such leading energy market companies as Iberdrola, Electricite de France, EDF Energy Networks, Red Electrica de Espana, National Grid Transco, Siemens PSE, Areva T&D and more.

Research of the experience to implement innovative technologies in the energy sector, which has been reflected in the implementation of projects such as Smart Grid, provide the following conclusions. Each project has its own purpose, strategy and implementation algorithm, stakeholders, but they all contribute to improving the socio-environmental and economic performance of the city or country. A key feature of the projects being implemented is the attempt to comprise as many stakeholders as possible; to acquaint the population with the benefits of Smart Grid and to enable the implementation of projects in different locations, that is, the design of the project is carried out in such a way that it can be adapted to the conditions of other countries and territories.

The formation and implementation of Smart Grid projects is not only a complex process, but it also requires a financial investment. That is why not all smart grid implementation projects are successful.

5.3 Problems in implementation of the Smart Grid projects

Despite the fact that "smart" innovation networks are capable to solve many energy issues, there are still barriers to the implementation of the Smart Grid concept in foreign countries. These barriers are related to the adaptation of new technologies, socio-economic problems, lack of policy and public awareness.

For example, India has encountered such barriers when designing smart grids (Kappagantu et al., 2018):

- the existing grid system is insufficient to meet future needs for clean energy and distributed generation;
- in India, several power grids are unevenly connected to the national grid;

- Cybersecurity issues are under-explored. Connecting a network to a cyber network causes many vulnerabilities in the system, which in turn are unexplored. Cybersecurity is one of the major problems for operation, as any particular loophole has the potential to turn into a disaster for utilities and networkers. In fact, the smart grid has a multi-layered structure and each layer requires specific security issues. Today, there is no single, universal system for protection against cyber threats. Therefore, there is a need to develop advanced technologies to tackle complex, evolving cyber threats;

- saving problems: since electricity production from renewable sources is not uniform, i.e intermittent and variable, it may require to be saved. The battery, the most common storage device, has a very short life of 4-5 years. The problem with pumping methods is that it requires large areas as reservoirs, which are usually only accessible in mountainous terrain. For the significant growth of the Smart Grid, this option requires distance from the pumping storage in the mountain ranges. In some regions of Germany, in practice, compressed air is stored in underground storage facilities that can be used to generate electricity when it is necessary. Despite its efficiency, the complexity of designing such a repository becomes an obstacle to implementing this technology. The most common method to store electricity includes batteries, the most popular being lead-acid batteries. Portability is their advantage, but low energy density, weight and size are a challenge for innovators to research. In addition, the high cost and risk of a lack of raw materials for batteries is also a serious problem. Research is being done to increase efficiency and reduce the cost of storage technologies, Advanced Lead Acid Batteries, Flow Batteries and Lithium Ion Batteries are options that are being considered in the Smart Grid project in India for large-scale storage;

- variants that are considered in the Smart Grid project in India for large-scale storage;

- complicated data management system. Smart Grid system includes a huge number of sensors, controllers, specialized equipment that helps to obtain data to predict electricity demand, price. Smart Grid unit data such as weather forecasts, security cameras, etc, increase the ability of operators to obtain an accurate analysis of energy supply issues and avoid them in a timely manner. Volumetric data from Smart Grid devices are difficult to collect and to store. The high volume of data can slow down the analysis and reporting process.

- problems of communication technologies. Most technologies have their own limitations. Some technologies have limited throughout capacity, others operate at a limited distance, the others have greater data loss, and some have limited success in underground installations. Thus, despite the many benefits, communication technologies for Smart Grid are poorly studied;

- socio-economic challenges. Technology becomes irrelevant if it cannot attract investors or users, resulting in the failure of pilot projects, the abandonment of new technologies, etc. among stakeholders;

- the financial instability of energy companies;

- the negative perception of Smart Grid stakeholders by the need to introduce new technology, high investments, lack of accurate information, etc .;

- lack of public awareness;

- fear of moral ageing. Consumers are well aware of how fast new technologies are becoming obsolete, despite the additional benefits which they provide;

- consumers' fear of new tariffs. At present, consumers who are satisfied with the current tariff scheme do not approve a new scheme that can operate under the following conditions: a low tariff on peak loads and tariff increase in peak periods;

- the impact of Smart Grid technologies on human health. Some consumers have concerns about radio frequency signals which are transmitted from Smart Grid devices. However, there is no precise data in this direction that played a role either in favour or against such claims. Deep research is required to solve such issues;

- mismatch of actions and interests of project coordinators;

- shortage of expert labour-power.

- resistance to automation changes by employees of energy companies.

During the implementation of Smart Grid Technologies in Africa, the following issues arose (African Utility Week, 2013):

- outdated infrastructure. The infrastructure in the country is inadequate and needs a major modernization. There is a need for new technologies and systems for power supply, namely transmission and distribution;

- the high cost of implementation. Electricity distribution systems make up the bulk of the cost of implementing a smart grid;

- a complex system for managing a large amount of data generated from a wide range of stakeholders, such as the authorities, utilities, suppliers, municipalities and consumers;

- the complexity of existing systems modernization. Outdated systems cannot always be upgraded with new technologies, so there may be a need for whole technology;

- "smart consumers". Customers are the stakeholders for whom the entire network is created, so there is a need for communication with consumers, the introduction of dynamic pricing, which can be an incentive for consumers, the need to change their own model of energy use;

- incompatibility of old equipment. Some outdated equipment needs to be replaced because it cannot be upgraded to be compatible with smart grid technologies. Early disposal of equipment can be problematic;

- smart cybersecurity. Using the Internet with lots of data between utilities and clients creates the need to solve cybersecurity issues;

- lack of Smart Grid technology standards system that can take years for development;

- providing energy to the population at affordable prices to meet their own needs;

- improving energy efficiency through the use of energy sources based on the principle of environmentally sustainable development;

- necessary changes in regulatory policy;

- lack of human skills.

The author's study (Faizan, 2019) identified six major problems that need to be solved when implementing Smart Grid:

- control of electricity distribution by automation of substations and switchgear, weather forecasting system and software;

- application of sensory and measuring technologies consisting of complex monitoring systems, dynamic linear technologies, fibre-optic temperature monitoring systems and special protection systems;

- improvement of interfaces and decision support technologies to enhance human interface and networking capabilities when using appliances and other electrical equipment;

- improvement of energy technologies components such as fuel elements, microwave technologies, ultracapacitors, sodium-sulfur (NaS) and lithium batteries;

- application of integrated communication;

- development of cybersecurity standards to make the system resilient to attacks and enable rapid recovery.

Based on the analysis of scientific works of leading scientists and foreign experience, it was found that the main problems of implementing the concept of Smart Grid in foreign countries are: - regulation and legislation; industry; technology; culture and communication (Fig. 12).

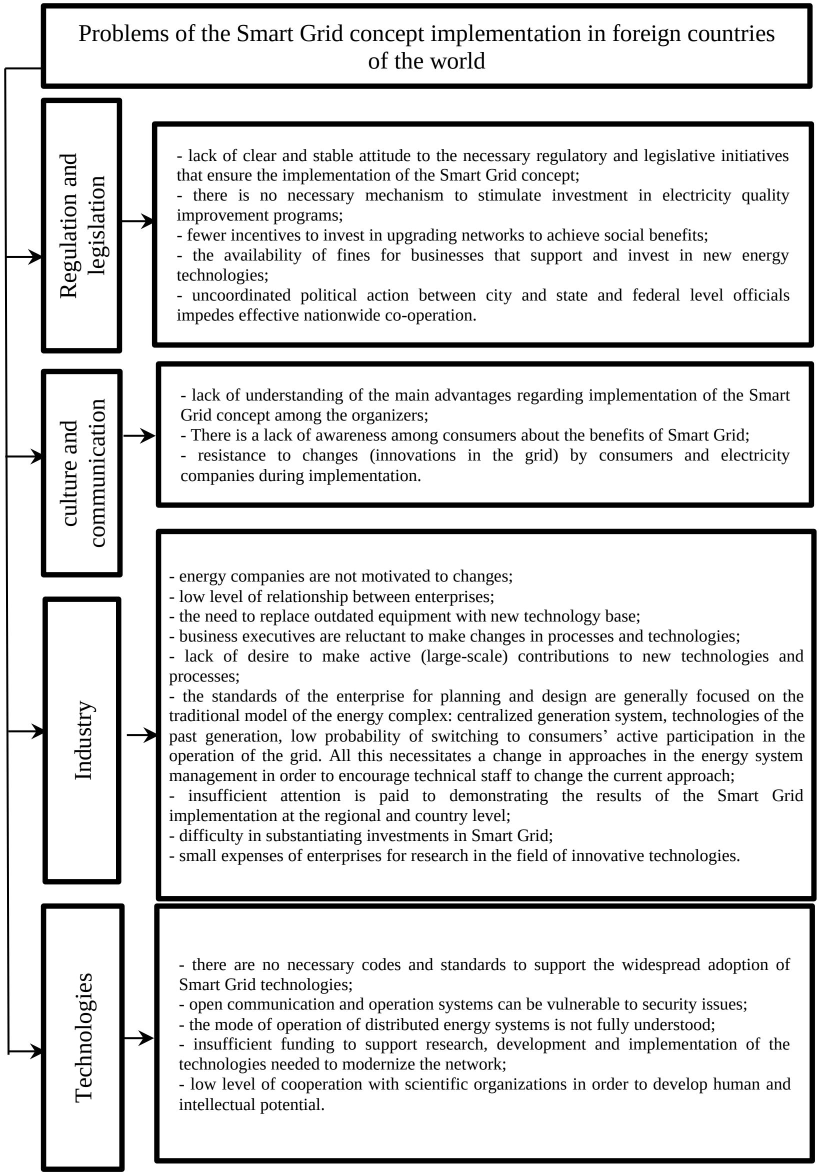


FIG. 12. PROBLEMS OF THE SMART GRID CONCEPT IMPLEMENTATION IN FOREIGN COUNTRIES

Thus, analysis of literature sources on energy development issues in foreign countries showed that the main problems of the Smart Grid concept implementation are the following: outdated technologies that require great costs, underdeveloped infrastructure, lack of experienced specialists, lack of regulatory framework, which would regulate and encourage energy industry entrepreneurs to implement smart technologies. It should also be noted that countries do not have the same potential to implement the Smart Grid concept. Some countries have limited financial resources, time resources, human resources, climate, etc. A very important aspect includes the socio-psychological barriers: resistance to changes in the labour resources involved in the energy sector, ignorance of the population and potential partners about the benefits of implementing Smart Grid, fear of project implementation failure.

CHAPTER 6. COMMERCIALIZATION OF ENERGY INNOVATION TRANSFER. ECONOMIC AND ENVIRONMENTAL ISSUES

The energy sector is critical in today's economy. The close relationship between energy and all other sectors of the economy and areas of human activity is why changes in the energy sector affect the economy's development, the transformation of individual industries, and the economy. The interdependence of technologies and the impact of industries on each other is now so significant that it is necessary to take a systematic approach to each industry's development, considering the potential effects that may occur in others.

Energy is a unique industry. It ensures the development not only of individual sectors but also supports modern civilization. On the one hand, energy technologies respond to society's growing demands, the achievement of technological progress. On the other hand, the development of energy technologies accelerates the effect of different industries. That is why energy is essential to ensure technological advancement and increase the number of innovations in production and non-production areas. The development of smart grids, the implementation of the principle of distributed energy generation, the creation of self-sufficient energy microgrids, the growing share of energy generation from renewable energy resources, the widespread use of intelligent technologies - all these are just some of the technologies that will replace the traditional energy system. Simultaneously, the introduction of innovative technologies in the energy sector increases the power grid's efficiency, quality characteristics, and creates new opportunities for deep integration of energy and other sectors of the economy, its deep penetration into all spheres of human activity.

The integration of energy technologies into the productive and non-productive sectors of the economy is characterized by evolutionary growth. It is easy to trace by tracking the development of energy compared to the economic growth indicators of vital economic sectors and the economy.

The transfer of innovative energy technologies, their spread in both the energy sector and energy-related industries, is a priority to increase the use of innovative technologies and the formation of conditions for technological development. It contributes to sustainable economic growth at the level of national economies and the international economy.

In a market economy, where the search for competitive advantage and the creation of value for the consumer are vital activities for companies in any field of activity, technology transfer is a natural and understandable process. It provides evolutionary technological development, which is an essential component of sustainable economic growth. The capitalist model of management allows automating to disseminating effective technologies without significant state intervention in these processes and manual control. For a considerable technology transfer process in such a system, it is enough to create a legislative field and an investment-friendly environment. It is a good impact. However, the efficiency of technology transfer, including in energy, is determined by several parameters.

Among such parameters, it is worth noting a group of indicators that characterize the pace of technology spread within the energy sector and beyond.

To ensure the rapid development of innovative technologies and their introduction into the productive and non-productive sectors of the economy, it is usually not enough to create adequate legal support and promote investment in the economy. It is necessary to develop an organizational mechanism that will transform innovative technologies fast and efficiently.

Effective transfer of innovations contributes to the economic effect at the energy sector level, other sectors of the national economy, national, regional, and world economy. An essential aspect of innovative development in energy is to obtain an environmental effect. New technologies are more environmentally friendly. Accordingly, their widespread implementation can solve complex problems related to the unsatisfactory state of the environment and the ecological system's damage due to human activities. New technologies help reduce emissions of harmful substances into the atmosphere and reduce greenhouse gas emissions. It brings closer the commitments of many countries worldwide to reduce greenhouse gas emissions and prevent climate change. It is one of the priorities of the civilized world.

However, the advanced technical characteristics of equipment and devices that help solve the problem of reducing the harmful load on the environment are only one aspect of obtaining the environmental effect of introducing innovative energy technologies. Another critical factor, which, together with the improved technical characteristics of equipment and devices used in energy, allows for a significant synergetic effect, is a change in approaches to building an energy system. The traditional energy system is based on a conceptual scheme developed in the middle of the twentieth century. The effectiveness of this scheme has been proven and not questioned. The main criterion of its efficacy is achieving the energy system's ultimate goal in the twentieth-century paradigm. The aim was to ensure constant, uninterrupted access to the energy resources of the economy, households, and other entities and facilities. The traditional energy system solved these problems. However, the effectiveness of this task over time began to be questioned. The question arose about the price that society has to pay to achieve this goal. The inclusion of additional parameters in evaluating the energy system's efficiency has led to a change in the vision of what the energy system should be to be called efficient. Achieving the system's primary goal - ensuring uninterrupted access to energy resources of all subjects and objects of society - has become an insufficient characteristic for developing new energy networks and modernization of existing ones. Additional factors introduced into the energy efficiency evaluation system relate not only to the economic value of achieving the energy system's primary goal. They relate to ensuring harm to the environment, population, and the world as a whole and promoting sustainable development and dissemination of innovative technologies in the energy sector and the economic system.

The vector of development of society, based on sustainable development principles, involves implementing efforts to obtain clean energy in the most accessible and economically justified way.

New requirements for the energy system as a component of the national economy, a significant factor influencing the development of other industries, have necessitated a technical and technological renewal of the energy system and changes in its construction principles.

A striking example of the energy system restructuring is the development of smart energy networks as an alternative to the existing energy system. Smart grids are considered an unalterable direction for developing the future energy system in the current economic and environmental realities. The principles on which smart energy networks are based meet all modern requirements and create opportunities for further deep integration of energy into all spheres of human activity on the principles of environmental safety and innovative development.

The components of smart energy networks that have the most significant impact on developing environmentally safe and innovative energy networks of the future should be singled out.

Application of distributed energy generation. Distributed energy generation opens up opportunities that could not be activated under the energy system's traditional model. The traditional energy system provides energy at powerful energy generation facilities, so powerful that they could provide power to extensive production facilities (e.g., factories, factories) and some areas of large cities. Without rejecting the possibility of energy generation at high-power energy facilities, distributed energy generation significantly complements the traditional energy system's capabilities. The ability to generate energy at facilities that are not fully energy-efficient creates new options for balancing the grid, increasing the energy supply's reliability, and increasing the energy generation process's environmental friendliness. The latter is associated with significant difficulties in upgrading powerful energy generation facilities. These difficulties are associated with substantial financial resources for the modernization of equipment, reducing fossil energy resources in energy generation, and replacing these resources with renewable ones. This technological complexity is sometimes a much more significant obstacle to transforming energy generation facilities to modern requirements than economic constraints.

In some cases, the re-equipment of a power generation plant is such a difficult task that the cost of its implementation is comparable to the construction of a new facility. It is a significant factor hindering the development of the energy system following modern requirements for it. Therefore, despite rapid technological growth, the energy system's renewal is slower than it could be. Also, unresolved several important technological issues are holding back changes in the energy system. Distributed energy generation allows the implementation of an approach to the modernization of the energy system, consisting of the gradual renewal of the technical and technological base of energy generation. It is possible due to the creation of power plants directly at energy consumers. Organizationally, this was made possible by the reform of the energy market, which allowed the sale of surplus energy produced by non-energy facilities to the grid. Technologically, this has become possible due to scientific and technological progress, the development of technologies for energy generation, accounting, and distribution. The traditional energy network has significant limitations on the ability to sell surplus energy produced by non-energy companies. We can observe the overcoming of such restrictions and difficulties that arise, on the example of reforming Ukraine's energy market.

One of the most critical features of distributed energy generation is that it usually involves alternative energy sources. In most cases, such references are solar and wind energy, less often subsoil energy and biofuels. It means that distributed energy generation contributes to transforming the energy system towards clean energy production. Even partial implementation of this principle in the traditional power grid increases its environmental efficiency. These affect the reduction of environmentally harmful effects on the environment and the population, contribute to the fight against climate change, and at the same time, adapt the energy system to the course of building a carbon-neutral economy.

The relationship between distributed energy generation and alternative energy allows developing one direction to form another simultaneously.

Maximum use of alternative energy. Another vital area of building smart grids is the use of alternative energy sources. The development of this direction allows replacing fossil non-renewable energy resources with renewable ones. It can significantly improve environmental pollution, minimize damage to nature during the extraction of fossil energy sources, and help curb climate change. The importance of this area and its strategic role in overcoming the environmental crisis has been confirmed in strategic programs for developing the energy sector, individual countries and intergovernmental organizations, such as the European Union. These plans provide for a rapid increase in the share of renewable energy in the structure of energy generation.

Thus, the development of the energy system is constrained by two types of factors. The first type is related to technological limitations that have not yet been resolved. It also includes technological constraints that can be addressed using innovative technologies, but such technologies are economically unjustified. That is, the costs of implementing such technologies outweigh the benefits. This type of factors hindering the energy system's transformation is not solved in the short term without a technological breakthrough.

Simultaneously, there are other types of factors that hinder the construction of an energy system that meets modern requirements and consumer demands. These are factors related to the low, or lower than desired, rate of spread of energy innovation. These factors can be eliminated by using organizational and economic levers. This issue is especially crucial in terms of the energy sector's great importance for developing the entire financial system. That is why it is advisable to pay attention to the transfer of energy innovations that accelerate new technologies. It is a question of creating preconditions that will provide market mechanisms for forming a favorable innovation environment. The innovative environment will ensure the interaction of all stakeholders in the processes of research, development, and testing of equipment prototypes and the creation of new technologies, improvement of existing technological processes, testing and practical use of innovative products, their distribution within energy supply chains and other industries. It is related to energy. An essential aspect of the energy sector's innovation policy is creating conditions for the diffusion of innovations through their vertical and horizontal transfer.

For creating a mechanism for the transfer of innovations in the energy sector, it is necessary to eliminate those restraining factors, the impact of which can be overcome without making a technological breakthrough. The main lever in this mechanism should be the commercialization of innovations at each stage of their life cycle. This approach, which is based on the commercialization of innovations, will ensure the intensification of innovation policy and dissemination in two directions. The first direction is the spread of innovations from the developer to the company that will apply them. Another direction is from the local enterprise to the local, regional, national, and international levels.

However, creating an innovation transfer mechanism is a difficult task. After all, the dissemination of innovation as a process brings together many stakeholders in many functions. Each of which has specific features and requires special attention. For determining the components of innovation transfer, it is necessary to analyze each element of this process separately and define the principles of interaction of stakeholders, technological and organizational, and economic features. That is, take into account each process's specifics, which is part of the transfer of innovation in energy.

The commercialization of the transfer of energy innovations as the main driver of the development of an innovation-friendly environment requires a detailed consideration of the main issues that play a significant role in shaping the mechanism of commercialization. A key aspect in this regard is the use of market mechanisms. To do this, you need to determine the prerequisites for their widespread use. An essential element of energy innovation is the technological aspect associated with creating new equipment and new modifications to existing ones. Therefore, it is advisable to pay special attention to technological entrepreneurship. Technology entrepreneurship has several definitions. However, in any case, technology entrepreneurship focuses on the development of companies and regional economic development. To ensure both the economic growth of the region and the development of an individual firm, technology entrepreneurship involves forming a list of stakeholders to bring ideas to market and train professionals involved in each stage of bringing innovative products to market. Such specialists are managers, engineers, and researchers. In particular, Bailetti (2012) defines technology entrepreneurship as "an investment in a project that brings together and uses professionals and heterogeneous assets to create value for the firm." Technological entrepreneurship is a unique form of organization of innovative activity of the company, based on the use of separate project management approaches to the formation of process management of innovative development. Knowledge management plays a unique role in building an entrepreneurial environment to develop innovative products, transfer, vertical, and horizontal distribution. According to Preston (2001, p. 2), it is crucial to create the factors of creating a favorable environment for the development of technology entrepreneurship include a system of stakeholder relations, managerial talent, intellectual property protection tools, entrepreneurial behavior, conditions for transparent and efficient investment, speed of creation and dissemination of innovations, high-quality products that sell quickly, flexibility, good location and the availability of clusters. Thus, agreeing with the above opinion, it is necessary to approach forming a favorable investment environment systematically. Creating appropriate conditions for the transfer of innovations in the energy sector requires preconditions for the formation of technological entrepreneurship.

One can take the opposite view and suggest that technology entrepreneurship does not play a significant role in the transfer of innovations, their horizontal and vertical distribution, the emergence of diffusion. The argument in favor of this view is the presence of progress and innovation results in an environment where no attention is paid to technological entrepreneurship, or technological entrepreneurship is not considered a phenomenon. At first glance, such an argument has a right to exist. After all, the innovation process is widespread. Innovations are created anywhere in the world that can be found on the map. Some innovations are implemented in the real sector of the economy, partially change or completely restructure technological processes, update technological equipment, create new approaches to existing, structured and semi-structured tasks, or solve previously unsolved problems. Also, there are different sources of innovation, which makes innovation diverse and sometimes unpredictable. World experience, the practical activity of many companies, testifies to a considerable variety of circumstances in which innovations are carried out. There is a discovery of a new product, approach, or technology. It is worth noting that sometimes innovation is the result of chance, unplanned action, an unexpected side effect. However, this does not diminish the importance of innovation, its role in developing individual industries, or the improvement of construction conditions. It depends on the specific product or technology that has been invented. However, the question arises as to how significant such unsystematic and disordered innovation is. What are its results in absolute terms? How these results relate to innovation potential. How many innovations remained unrealized, how many inventions were not implemented, how many inventions went unnoticed, and therefore were not transformed into useful products or services?

The answer to these questions is challenging to find empirically. But the experience of activity in any field, as well as the practice and theory of modern management, allows us to give an unambiguous answer to the question of which action is more effective: organized or less organized? Professor Oleg Balatskyi, a prominent scientist and the School of Environmental Economics founder in the Soviet Union, said: "Everything bad comes, everything good needs to be organized." There is no doubt that organized activity has a better result due to the purposeful impact on the object of management. Determining the factors of influence, development drivers, stakeholders, expected direct and derivative products allow a comprehensive approach to solving the problem, the organization of certain activities. The system approach allows using more fully the potential of the managed system. It is also true for innovation development management.

The use of innovation potential is complete for forming appropriate prerequisites for its use, developing an effective management system. Technological entrepreneurship is a tool for using innovative potential, its growth, the emergence of synergetic effects. Technological entrepreneurship as a tool for transferring innovation in energy can combine the two necessary components that form an effective system for disseminating innovation. Firstly, the formation and maintenance of an innovative environment. Secondly, market mechanisms for transferring innovations through their commercialization at all stages of the life cycle of an innovative product. The importance of technology entrepreneurship for regional development is often underestimated. It is a misconception because technology entrepreneurship expands the scope of partnerships between developers of innovative products, energy companies, enterprises in other industries, local and state authorities, financial and investment institutions, local, regional, state, and international institutions, and civil society. The useful activity of business entities in the framework of technological entrepreneurship contributes to the formation of clusters. The transfer of innovations is accelerating within these clusters. And synergetic effects from intersectoral interaction are emerging. A special place in the construction and development of these clusters is occupied by research and educational institutions that create the basis for the sustainable and long-term development of the innovation environment. Thus, the expected effects of clustering will be an increase in the number and quality of commercially available research and development, strengthening intellectual property protection mechanisms, creating innovation and business incubators, business growth based on innovation and know-how, increasing the share of high-tech companies, new knowledge-intensive business units.

In the conditions of forming technological entrepreneurship to obtain the expected results, special importance is given to educational activities. It is impossible to develop a favorable environment for innovation based on technological entrepreneurship. Technology education for entrepreneurship (Byers, 2005) has become a unique entrepreneurship education (Frank and Boocock, 2008). The definition of entrepreneurship education is that it is "aimed at achieving a culture of learning that will increase the number of students who can identify, create, initiate and successfully manage personal, business, work, and community opportunities" (Ed-ventures Magazine, 1997).

The development of entrepreneurship education contributes to the transfer of innovation and the formation of a favorable environment for this. The effect of this is much more comprehensive. It is essential for the development of the entire economic system. It creates initiative among the details of more people. Simultaneously, entrepreneurship education develops skills and abilities for entrepreneurial activity, which promotes revival in the business environment and creates a highly competitive economy.

Given the above, the formation of technological entrepreneurship has the expected results, which go far beyond the system of innovative energy development, the spread of innovative energy technologies within the energy sector, and related industries. Technological entrepreneurship changes the basics of doing business, transforms the previously formed foundation of economic development, creates a more flexible business environment, and adds dynamics to enterprises' economic growth, individual territories, regions, and countries. The result of technology entrepreneurship is a catalyst for strengthening market mechanisms for developing the financial system. However, without consistent and systematic development of entrepreneurship education, it is impossible to achieve the maximum possible results from technological entrepreneurship in the economy as a critical determinant of its growth.

The next important issue to be considered in forming an organizational and economic management system of innovative development in the energy sector and the formation of the mechanism of energy innovation transfer is the policy on innovation technology transfer carried out by local and state authorities and international organizations associations such as the European Union. In the general case, a policy is a system of actions and measures to exercise managerial influence on the managed system to obtain the desired results. It is crucial to answering the question, what is the current and what should be the policy in the field of technology transfer to provide optimal conditions for the spread of innovation in energy and the formation of preconditions for the diffusion of innovation? What factors are taken into account in the development of technology transfer policy as determinants of horizontal and vertical dissemination of innovations in the energy sector and related sectors of the economy? What measures are aimed at different recipients in this process? What incentives are used to motivate business representatives, the scientific community, private research centers, the general population, and its social groups to use innovative energy products and technologies? How effective are these incentives?

The development and implementation of a policy to promote the transfer of innovative technologies is aimed at solving a set of tasks. Among such studies, it is expedient to single out overcoming inequality between regions within one country or overcoming inequality between individual countries. For example, the different economic and social development levels between the European Union member states cause problems related to ensuring high living standards, creating opportunities for economic growth, and the introduction of innovative technologies. In particular, in the energy sector, this problem is related to the need to create a pan-European energy network, which will be based on the achievements of scientific and technological progress and the principle of intellectualization, in particular, the development of smart grids. However, the transformation of the energy system built on a traditional scheme (with limited capacity for distributed energy generation, limited capacity for alternative energy production, lack of total coverage of system components with energy meters) meets some economic and technological limitations. How significant these restrictions mainly depend on the economic development of countries. Thus, one of the policy's tasks in the field of innovation technology transfer is to close the development gaps between individual regions and countries, which means the ability to innovate and facilitate technology transfer. Given the presence of intersectoral cooperation in the dissemination of innovative energy technologies and the presence of synergetic effects arising from the interaction of stakeholders to accelerate the adaptation of scientific developments to market needs and their further commercial application, creating relatively equal conditions for energy development and the economy as a whole is a critical task.

Further growth in inequality will create preconditions for future serious problems related to income redistribution and social justice maintenance. It is believed that imbalance is most common in peripheral or industrially depressed regions. In areas where low technological development can make it difficult to access knowledge, technology, and human resources. It will affect individual business units' outcomes in these areas and the indicators of efficiency and effectiveness of regional innovation systems. Innovation policy, especially concerning technology transfer, must be tailored to local development and consider the problems of economic inequality between regions and countries. Thus, the developed programs and initiatives should provide differentiated approaches to the organization and promote innovation transfer in different areas and countries. In the past, European policies have facilitated cooperation between companies and the exchange of technologies for collaboration "far from the market" (to the stage of the competition) (Brychan Thomas, 2015).

This approach to energy innovation transfer policy is based on the use of large companies' strengths, which can afford to maintain departments for research and experimental testing of equipment prototypes. However, as a result of such a policy to support the transfer of energy technologies, small and medium-sized companies were in a situation of limited opportunities. After all, such a support system allows obtaining innovative technologies, including large, financially powerful companies. Small and medium-sized companies do not have access to private developments that are protected by intellectual property rights. Simultaneously, small and medium-sized companies do not have the potential to carry out their innovative, inventive activities. Buying large companies' developments is problematic, both from the standpoint of their high cost and for large companies' reluctance to press (sell) their consequences to competitors. In this situation, it is obvious to give a competitive advantage to large companies and limit small and medium-sized companies' capabilities.

Moreover, such discrimination is due to the implementation of international, state, and regional programs to develop the innovation environment and the transfer of innovation. Ultimately, this approach is not conducive to an efficient innovation transfer process. On the contrary, it restrains the spread of innovative energy technologies and any other technologies by creating a discriminatory market position. Support for small companies (and medium-sized companies) is a critical task in developing and implementing policies for the transfer of innovative energy technologies because they are in close contact with the consumer. These companies are in fierce competition conditions and are interested in rapid innovative development to gain a competitive advantage in the market. It is through such companies that innovation can be spread most quickly. It will accelerate the transition of innovative development from one stage of the life cycle to another within the supply chain of innovative energy technologies. After all, small firms often participate in strong interactions close to the market, working on developing products or processes in the vertical chain supplier-manufacturer-customer. As a conclusion from the above, the existing policy of supporting large companies, which is still often observed in many countries and regions of individual states (including lobby groups), needs to be revised. Existing innovation technology transfer and innovation programs need to be adjusted to reflect the importance of vertical links and close to the market to respond to formal and informal technology sources to which small firms have access (Brychan Thomas, 2015).

The policy in the field of transfer of innovative technologies in energy should consider the interests and provide for the behavior of all actors involved in the process: customers, suppliers, manufacturers, competitors, research institutions, including universities. Also, a necessary condition for forming an effective organizational and legal mechanism to support the transfer of innovation is to take into account the peculiarities of the process of developing innovative products (technology), adapting scientific development to market requirements for its commercial dissemination, and enhancing research capacity.

It is also imperative to take into account the sources of innovation in the development of policy in the field of innovation and the transfer of innovative technologies in the energy sector.

Suppose we abstract from the features of the innovation process and technology transfer in the energy sector. In that case, we can use a study by one of the founders of modern management, Peter F. Drucker, to determine innovation sources. He identified seven sources of innovation (Peter F. Drucker, 1993):

– unpredictable;

– discrepancy;

– urgent need;

– market and industry structure;

– demographic factors;

– new knowledge;

– changes in perception.

Despite the fact that the work of Peter F. Drucker, which identified these sources of innovation, was published in 1993, the relevance of the results of this study is not lost in our time.

It should be noted that in this form, the source of innovation is difficult to interpret to be useful in the preparation of individual programs to support innovation development, and the formation of the foundations of international, national, or regional policy in this area. The sources of innovation presented in this form are more suitable for constructing strategy and management systems for innovative development and dissemination of innovative technologies at the enterprise level. It can develop an approach to support innovation in the enterprise, eliminating the potential loss of opportunities to develop an innovative product, technology, or service. However, this classification of innovation sources allows predicting specific trends and processes in the innovative development of individual enterprises, regions, or countries. In particular, the analysis of external sources of innovation concerning the organization (enterprise, company) allows us to predict possible directions of the development of innovative technologies and predict their basis based on economic entities' behavior. It will form a compelling set of tools for managing innovation development, promoting the transfer of innovative technologies. The purpose of creating such a set of tools of influence is to support economic entities to maximize their potential for innovative development (enterprises, regions, countries) and intensify market mechanisms to promote innovation. It will ensure the horizontal and vertical transfer of innovations based on their commercial transfer and minimize authority's and institutions' administrative influence on this process. That is, it will help to displace executive power by market mechanisms.

The ultimate goal of the policy in innovation and transfer of innovative technologies should be their diffusion. Having achieved the diffusion of innovations, international, state, or regional policy completes its primary task. After that, market mechanisms replace administrative influence. The economic system is moving to the vector of innovative development. At this stage, the system becomes self-managing and does not require significant intervention for effective operation. The role of policy in innovation and transfer of innovative technologies is changing from the formation of the system to the implementation of corrective actions to maintain the desired trajectory of its development.

The diffusion of innovations in energy is achieved under many conditions. Some of these conditions were somehow described above. In particular, it is expedient to talk about the diffusion of innovations only when the system of their transfer is formed and functions. Such a system can function effectively for an extended period only based on the use of market levers. The practice of economic activity evidences this. The comparative efficiency of the system of innovation development and transfer of innovations decreases with the long-term influence of administrative levers and the presence of a significant time lag of transition from them to market mechanisms. There is a similar situation to the case with incorrectly placed strategic priorities in the formation of innovation policy, including the transfer of innovative technologies. The competitive environment, which acts as a catalyst for the interaction of stakeholders in the transfer of energy innovations, is not formed. It destroys the basis for the transition from the stage of transfer of innovations to their diffusion. It is because innovations from the energy sector do not penetrate related industries. The mechanism of such penetration - intersectoral interaction of stakeholders - is used to a limited extent. The diffusion of innovative technologies in energy requires not only the availability of innovative technology, which can be vertically or horizontally distributed among stakeholders. It is not enough for its formation. Diffusion of innovative technologies in energy can occur if there is a sufficient level of integration of market participants in innovation processes locally within a clearly defined territory (this leads to the formation of innovation clusters) or globally without clear territorial restrictions.

An essential role for the formation of the diffusion of innovations is played by exchanging information and educational resources between the participants of the innovation process. Potential customers or users of innovative technology should be able to get acquainted with the technology and then try to evaluate it. That is, access to the test use of innovative technology must be provided. At this stage, the process of learning to use technology or equipment. Also, at this stage is collecting data necessary to assess the quality and correct operation of innovative technology (or equipment). These data can then be used to improve the innovative product. They can also be used to develop other innovative products.

Information about the technology should be disseminated, and market participants should know the results of its application and features of work. It will arouse the interest of potential and actual customers. It will increase the speed of the spread of innovative technology, reduce the time required for its commercial use. that is, conditions will be provided for the transfer of innovative technologies in the energy sector on the terms of commercialization of innovations. When only a small number of companies that purchase innovative technology have received it for use, a small number of diffusers can create and disseminate information about the technology. Accordingly, they can distribute information about the experience of practical use of technology and the results obtained. They are mainly expanding the information base on the application of innovative technology. This small number of diffusers trigger the chain information wave, which increases the speed of horizontal and vertical transfer of energy innovations.

Thus, the interaction of stakeholders and the parallel dissemination of information about the experience of using innovative technologies, which take place in a favorable environment for innovation, form a network of transmission (transfer) of innovative energy technologies. Technology transfer networks allow achieving a shared vision for the development and application of new technologies. Essential aspects of technology transfer networks are their type and size. These innovation transfer networks' parameters depend on many factors that take into account the specifics of innovative technologies and their areas of application. However, there is a scientifically based opinion that small networks are more efficient because the communication between stakeholders is dynamic and straightforward. In any case, any type and size of networks are characterized by adaptation to changing internal and external factors and the ability to evolve. At the same time, it is essential to remember that while working with other technology networks provides access to a broader contact base. It carries some competitive risk (Brychan Thomas, 2015).

The transfer of innovative technologies in the energy sector has specific features. These features are due to the energy sector's role in the economic system and the deep integration of energy into every sector of the modern economy and every sphere of human life. The vector of energy economic development requires innovative technologies to increase the network's level of intelligence. It will allow the energy system to meet modern criteria for assessing its efficiency. For modernizing the energy sector, it is necessary to provide an effective mechanism for the horizontal and vertical transfer of innovation. For these purposes, it is required to create a favorable environment for innovation. This task should be addressed by developing policies to support innovation and the transfer of innovative technologies. The development of this policy should consider the peculiarities of economic development and economic growth opportunities of the region or country and focus on the formation of a self-regulatory innovation system. Thus the policy of support for innovation should be built to launch market mechanisms to disseminate innovative technologies in terms of their commercial use. To this end, several incentives should be provided to promote the development of a highly competitive environment, where the necessary condition for gaining a competitive advantage is the introduction of innovative technologies. Innovation support policies should also avoid provisions that discriminate in the market and restrict individual companies or groups of companies (usually small businesses) to innovative technologies. The active involvement of small enterprises in creating innovation networks is an essential factor in accelerating the transfer of innovation and the emergence of the diffusion effect. It is because small networks adapt more quickly to changing conditions and can absorb innovative products faster. The interaction between stakeholders in small innovative networks is more straightforward and more dynamic.

CONCLUSIONS

The European countries have gone a long way towards understanding the benefits of cooperation and collaboration in the energy field. In recent years, the European institutions have strengthened the mechanisms for effective interaction on the way to building a pan-European energy market, integrating national grids with the continental European grid. However, overcoming existing energy and related environmental issues requires the development of new energy collaborative benchmarks that can be based on smart technologies and the benefits of smart specialization. Such benchmarks include smart grid technology.

Given this, further international cooperation in the energy sector will involve upgrading the grids to meet market needs for safe and energy-efficient energy sources and clean energy technologies. The renewal process of the traditional centralized networks will be continued, not only because of their aging, but also owing to the need to adapt the grids to the renewable energy sources mix, to involve a very large number of users in the energy distribution and storage systems, to carry out continuous analytical processing of user information arrays. In order to achieve this goal, it is necessary to eliminate a complex of technical, social and economic problems. This is not just about technical re-equipment of networks, installation of new smart meters and sensors for customers to control their devices. Deploying smart and secure grids requires much more than just upgrading them technically. Unfortunately, many European countries lack the institutional and technological prerequisites to adopt smart energy technologies.

In addition, in the European countries, the issue of load balancing for the uncontrolled and unpredictable generation of energy from the use of alternative energy sources has not been fully resolved. Therefore, it is difficult to plan energy capacity and to form a pool of contracts under such conditions for long-term energy supply. It significantly increases the energy risks that EU countries may face in the full transition to renewable energy. And such an impact is not uniform since countries vary greatly in the level of technology development. However, some improvement from the existing fluctuations in the energy market may be provided by the development of energy storage comprehensive network across Europe in support of EU reforms.

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