Kharlamova G., Nate S., Chernyak O. (2016),
Renewable energy and security for Ukraine: challenge or smart way?,
Journal of International Studies, Vol. 9, No 1, pp. 88-115. DOI: 10.14254/2071-8330.2016/9-1/7

Journal
of International
Studies

Scientific Papers

Renewable energy and security for Ukraine: challenge or smart way?

Ganna Kharlamova
Taras Shevchenko National University of Kyiv,
Ukraine
akharlamova@ukr.net

Silviu Nate
Lucian Blaga University of Sibiu
Romania
silviu.nate@ulbsibiu.ro

Oleksandr Chernyak
Taras Shevchenko National University of Kyiv
Ukraine
chernyak@univ.kiev.ua

Received: October, 2015
1st Revision: December, 2015
Accepted: March, 2016

DOI: 10.14254/2071-8330.2016/9-1/7

Abstract. Nowadays, as most of the countries in the world pledged to the low-carbon future, global energy problems become more acute. One of the most promising ways to address the growing problems of energy supply widely considered by the international community is use of alternative energy source such as the renewable or „clean" energy. Renewable energy is highly praised for its wide availability and environmental friendliness and its decisive advantage over traditional energy is that it is not subjected to depletion like the fossil fuel resources and that it does not lead to the increasing pollution. The paper examines how renewable energy sources can be made useful in the case of Ukraine. Our analysis run along two dimensions: the EU and world's global tendencies as well as the internal current situation. Our main focus is on whether the investing in renewable energy sources can be regarded as a country's "smart" power policy and what the outcomes of turning to the renewable resources might be like over some time period in the future. On the base of statistical approach we came to the conclusions for Ukraine: 1) renewable energy sources (RES) production has a potential to replace oil, gas and coal sources, however the same could not be said about nuclear power; 2) the "green tariff" indeed makes renewable energy projects more attractive for investments; 3) RES production opens new projects in industry thus the employment rate in industry can grow, but not such could be said about agriculture; 4) in analyzed years RES production had very low level of impact on the economic performance; 5) RES have positive effect on the environment in Ukraine in analyzed period; 5) RES consumption has a potential to boost positive effects of alternative energy resources, more than even its production. That evokes the idea of necessity to implement policy and some actions to motivate namely private consumers and industry to increase the consumption of RES. Then it could obviously drive the increase of RES production.

Key words: renewable energy sources, energy security, efficiency, correlation, Ukraine.

JEL Classification*:* F52, Q28

INTRODUCTION

Nature is rich in energy resources. However, rash and irrational consumption results in a sharp reduction in non-renewable natural resources that sooner or later can escort to the global energy crisis. Currently most war conflicts globally have the ground on the energy resources allocation (Alao & Olonisakin, 2000; Billon, 2005; Escobar, 2006; Jewitt, 2008; Le Billon, 2001, 2007; Ross, 2004; Wegenast & Basedau, 2013).

Academics across a broad range of disciplines have been battling with the term "energy security" in terms of its measurement, its concept and its interpretation for a number of centuries. Energy security in the context of this research is defined as: *the association between the national security, the availability of natural non-renewable resources for the energy consumption and the potential to use renewable resources effectively.*

We suppose to consider the renewable resources as some lever weaken the tension that exists in the world. This aspect makes any research dedicated to the renewable natural resources as an extremely promising.

Besides, the attempts to access natural energy resources there is the problem of environmental pollution. It pushes the developed countries to modify its energy strategies and seek new ways to solve the energy problem. The EU set a goal to transit to the sustainable development. In the energy sector, the EU is making significant efforts to improve its energy security, increase the usage of renewable energy resources, and reduce the impact on the environment. The implementation of these measures, and achieved technological breakthroughs, particularly in wind energy and biomass usage, inspires more ambitious plans.

At present, Ukraine's urgent challenge is the integration of the domestic economy in the world, which should give some benefits from the participation in the international division of energy resources. Further, this expansion of international cooperation will require from Ukraine to implement agreed energy policy, which would be coherent policy, especially with the European Community. Energy problems in Ukraine have its own characteristics: first, Ukraine only on half provides itself with its own energy resources, and secondly, it is almost entirely dependent on a single distributor - Russia.

This creates the research question: *how Ukraine can become the energy secured country in the unison to the neighbours and the global tendencies?*

Policy recommendations are decision path premises for the development of an energy efficient community. Before the stage of policy recommendations, the analysis would bring the best know how by integrating good practices transfer and case studies, national resources assessment on the short and long term. Innovative strategic priorities should be taken into account.

By identifying the local/national needs, all the actors involved gain a certain degree of importance. They are no longer just simple beneficiaries of developed policies – they become human security providers. Therefore, the connection to European values and ensuring a citizen-centred transfer of good practices would ensure mutually beneficial interdependence between the existing resources and developed processes/implementation mechanisms – decision making output and legitimacy:

Changing the mentality of stakeholders in order to develop sustainable communities, remains the main global policy challenge.

As the hypothesis of the research, we could consider the possibility of reduction of energy dependence in the course of the development of energy efficiency and alternative energy source usage in Ukraine. To test this, the following logical line could be proposed:

– Think over the possibility to weaken neighbour tension by means of energy issues;
– Find out what types of clean energy (renewable energy sources (RES)) today are designed and can be used in practice for the most part efficiently;
– Review the effectiveness of non-conventional forms of energy on the example of world trends and the practice of excellence in developed countries;
– Assess how promising is the introduction of renewable energy in Ukraine.

ENERGY SECURITY AND RES: LITERATURE OVERVIEW

Ukraine deliberately or not, but is involved in nearly all mainly powerful games that are nowadays situated on the world chessboard.

According to Joseph Nye's Commentary about the American Power in 21st Century, the world distribution of power is three-dimensional chess game:

1. There is large unipolarity in the military power with great anxiety of the U.S. to remain the only superpower for some time;
2. There is already obvious multipolarity in the economic power for more than a decade. The key players are the U.S., Europe, Japan, and China. UN and others are gaining in importance.
3. "The bottom chessboard is the realm of cross-border transactions that occur outside of government control. It includes diverse non-state actors, such as bankers electronically transferring sums larger than the majority of national budgets, and, at the other extreme, terrorists transferring weapons or hackers threatening cyber-security" (Nye, 2009).

We could add the fourth: having in mind that points 1 and 2 are bound with the state energy supply, especially in the period of resource localization in other states; the energy security become an important lever for the further world development and global polarity. Energy issues change the balance. More repeatedly such opinions are shared, especially in aspect of energy issues: "If there ever was a time in which the United States could always be counted on to fill the gaps that may emerge in European defence that time is rapidly coming to an end" (Ivo Daalder, the U.S. ambassador to NATO, January 2012) (Barry, 2012). As even a slight look on the price volatility shows tight correlation between world policy and prices for energy resources (Fig. 1)

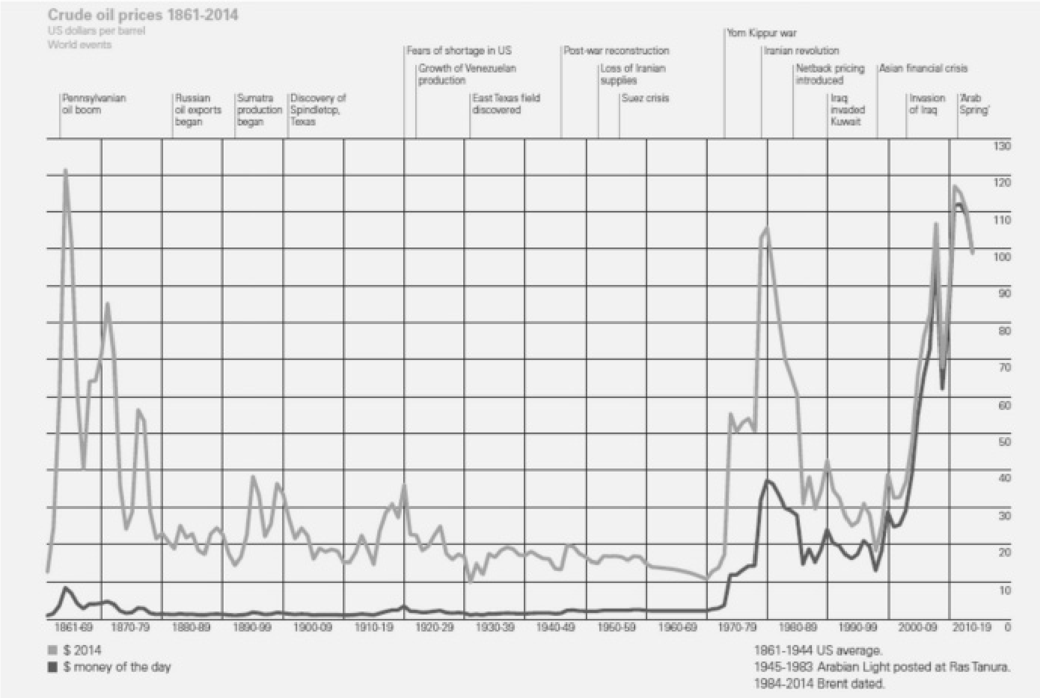

Fig. 1. Crude oil prices in history line 1861-2014

Source: BP Statistical Review of World Energy June 2015 bp.com/statisticalreview#BPstats.

Mentioned above adds to the Ukrainian crisis. Without Crimea, Ukraine seems to have lost a quite significant part of its economic and energy future: oil and gas fields in valuable offshore blocks lie of the Crimean peninsula (according to Ukraine Gateway; Broad, 2014). The Crimea peninsula represents about 20% and 40% respectively of total installed wind and solar PV capacities; 11 geothermal-circulation systems are operating (IRENA, 2015). Before the overthrow of former President Viktor Yanukovych, Ukraine was about to sign a contract with a group which includes Exxon Mobil and Royal Dutch Shell, prepared to invest $ 735 million to install two active wells on the south-west Crimea (Bierman, 2014). The so-called area Skifska that Shell and Exxon want to develop is a part of a marine extraction field which extends westward along the coast of the Black Sea to the Romanian territorial waters. This quantity amounts to about 20% of annual gas import of Ukraine. All new routes that supposed from Russia to Europe do not cross Ukraine (Economist, 2014; CIEP, 2014). Geopolitical interest resettlement towards Ukraine is closely connected to the mercantile projections with access to the territorial sea and extraction perimeters.

As to the global oil production the leaders are Saudi Arabia (526 million tons per year), Russia (509 million tons per year), followed by USA (352 million tons per year) (World Energy Council, 2016). Although, if one is to glance on the distribution of other energy resources the evidence of 2016 shows that among seven other possible sources of energy – Russia is in top-3 solitary in gas (occupying 1st position with 576 Mtoe per year), but USA are top-1 in nuclear, wind and geothermal energy sources, and are in top-3 as to coal, gas and solar. Generally, USA are out the top in hydropower. Other leaders in energy producing are France (nuclear), Germany (wind, solar), Italy (solar), Japan (nuclear), India (coal), China (coal, wind and hydropower), Canada (gas and hydropower), Pillipiness (geothermal), Indonesia (geothermal), and Brasil (hydropower). Thus, best practices of renewable energy producing could be taken to Ukraine from Germany (The EU) and China.

Literature review gives evidence that despite pro & cons in the efficiency and other market stimuli, mostly political decision making initiatives play important role for choosing the source of energy, especially in the aspect of RES (Balitsky, et al, 2014; Baublys, et al, 2014; Painuly, 2001). Hardly possible to find the research that argues in negative aspects of RES implementations. RES considered as a panacea for energy security (Akella, et al, 2009; Haas, et al, 2011; Sovacool, 2010), as well as one of the highly effective methods of carbon dioxide emissions reduction (Kharlamova, 2015a; Lutska, 2010). There are already enough researches which statistically confirm that renewable energy resources appear to be the one of the largely efficient and effective solutions (Dincer, 2000). Calculative surveys provide evidence of an intimate connection between the renewable energy and the sustainable development in the EU states and in developed countries without any concern (Balitskiy, et al, 2014; Chien & Hu, 2007; Henderson, et al, 2003; Institute for the 21th Century reviews; Grecu & Nate, 2014). However, there are still a few stumbling-stones in the RES launching over the world:

1. Despite the ambitious government targets to increase the share of renewable energy in many countries, it is increasingly recognized that social acceptance may be a constraining factor (Wüstenhagen, et al, 2007; Upreti, 2004).
2. There is not the available grid capacity to spread this RES produced energy over the country (Sorensen, 2011).
3. There is still no universal manual how to calculate energy efficiency of RES. How to make investments in RES plants more profitable in developing countries even without special regimes of government support and taxation (Short, et al, 2005; Bergmann, et al, 2006). Open question is in finding the balance point between prices and quantities regarding RES plants and RES production/consumption (Menanteau, al, 2003; Chernyak & Slushaienko, 2014).
4. There are still concerns about marine renewable energy in aspects of its potential benefits to biodiversity (Inger, et al, 2009). Thus, the deployment of marine RES has the potential to cause conflict among interest group, including energy companies, the fishing sector and environmental groups. Marine RES have the potential to be both detrimental and beneficial to the environment, but the evidence base remains limited.

As well, positive approach to the RES varies in aspect of intensity of their productive impact on the economy. There is the evidence that, for example, compared to non-OECD economies, OECD economies have higher technical efficiency and a higher share of geothermal, solar, tide, and wind fuels in renewable energy. However, non-OECD economies have a higher share of renewable energy in their total energy supply than OECD economies (Chien, Hu, 2007). Same diversity in RES positive effect absorption is marked for the EU states (Haas, et al, 2011).

If to search for the analyses of RES in Ukraine the great lag appears to be in studies that provide any calculative approach to RES efficiency, implementation prospective and, especially, in the interconnection with the EU tendencies (Kondratyuk, 2009; Kharlamova, 2015b; Tarasenko, et al, 2013). Taking into account these results, in the empirical part of this paper, we will use some statistical and calculative techniques to investigate the prospective of RES in Ukraine in harmonization with the world and the EU trends on the base of a time series data trends.

RENEWABLE RESOURCES: WORLD TRENDS

The arguments in favour of renewable energy sources (RES) can be considered as:

– First, local energy does not require fighting for it. As wind, solar and bio-resources can be used only where they are;
– Second, these resources are environmentally friendly, and its development provides an opportunity to invest in the local economy;
– Third, renewable energy is relatively cheap and inexhaustible (Kharlamova, 2015b; Clowes & Choros-Mrozowska, 2015).

However, the development of alternative energy requires significant investments. Renewables are among 25 projects across Europe that have won funding totalling €4.7 billion (£3.6bn) (according to Energy Live news). Large-scale energy projects, such as building solar and wind power plants, can only be implemented with government support. The developed countries like USA, Germany, Japan, and Denmark in its energy policy paid great attention to the development of the alternative energy sector. Germany was the first country in the world that legally enacted the use of renewable energy. According to the Law discounted prices for "green" electricity into the utility network were frozen for 20 years in Germany. In 2012, renewable sources provided roughly 13% of the United States' electric power production. Non-hydro renewables, which are generally more intermittent and produce less power, accounted for approximately 6% of production—more than twice what they delivered in 1990 (Institute for 21st Century Energy). According to the International Energy Agency, by 2030 the share of electricity produced through alternative sources will double compared with today's figures, which constitute about 16% of total production.

According to British Petroleum statistics, already in 2014 renewable power consumption grew by 12%, providing 6% of the world's electricity. Renewables contributed 42.5% of the growth in global power generation in 2014, representing 28% of world energy growth. The OECD remains the main source of renewable power generation (68% of world total in 2014) (Annex 2).

The European Commission believes that by 2020 Europe's fifth of the energy be produced from environmentally friendly sources. For now Europe has such hierarchy of renewable sources: hydropower (top 1- Sweden), wind and solar (top -1 – Germany).

In 2014 investments in renewables increased by 21% and amounted to 272.2 billion dollars. Reduced investing in the 2012-2013 could be partly explained by the uncertainty of policy incentives in the US and Europe and declining support in some countries. In developing countries investments in renewables increased by 36% to 131.3 billion dollars according to Bloomberg reports. While in developed countries – only by 3% to 138.9 billion dollars. The share of investments in developing countries has increased to a record in 49%, 63% of which was accounted for China. In considered 2014 increasing of green investment a major role was played by the boom of solar power plants in China and Japan for a total of 74.9 billion dollars. In 2014, over a quarter of new investments in renewables went to small-scale projects (about 73.5 billion dollars). Small-scale solar PV systems are distributed worldwide, mostly in developing countries, as an affordable alternative to the centralized network. Investments in renewables spread to new markets: Chile, Indonesia, Kenya, Mexico, South Africa, Turkey, where each country has invested more than $ 1 billion. in RES. Jordan, Myanmar, Panama, the Philippines and Uruguay invested from 500 million to $ 1 billion in RES. The 2014 year could be marked as the year of an increase in RES investment in all regions of the world. Meanwhile, China's share was 31% of the total. Investment in India grew to 7.4 billion dollars. The rest of Asia and Oceania 9% increased investment to 48.7 billion dollars. Investments in Europe rose less than 1%, to 57.5 billion dollars. United States invested more than 7% - 38.3 billion dollars (Bloomebrg, 2015; Renewables, 2015).

In 2014 the top 10 domestic investors consisted of four developing countries, and six developed countries. China accounted for 30% of global investment in renewable energy (83.3 billion dollars), followed by the US (38.3 billion dollars), then Japan (34.3 billion dollars), the United Kingdom (13.9 bn.), Germany (11.4 bn.), Canada ($ 8 billion.), Brazil (7.6 billion USD.), India (7.4 billion USD.), the Netherlands (6.5 bn.), South Africa (5.5 billion dollars). Net investments in renewable energy for the fifth year in a row (in 2014 - 242.5 billion dollars.) were prevailing over fossil fuel (132 billion dollars) (Global status report, 2015).

Investments by type of technology vary as well in 2014. Thus, investments in solar energy increased by 25% to 149.6 billion dollars and counted 55% of all investments; in wind energy - by 11% to 99.5 billion dollars (36.8% of all investments). The remaining 8% were directed to energy from biomass and waste (8.4 billion dollars). In 2014, developing countries still spend most of investments in wind energy, small hydro and geothermal energy. Developed countries have kept most of the investments in solar power, but their share dropped to 58% due to a surge in China, which has invested more than 25% of the total. The best country in solar energy investor was Japan, which accounts for 23% of the global total, followed by the US (19%). The best investors in wind energy were China (mainly due to expected reductions in tariff), UK, Germany, Netherlands, Brazil and India. Other renewable energy technologies showed contrasting trends: investments in small hydropower increased in developed countries, but declined significantly in developing countries; geothermal energy and biofuels declined in developed countries, but increased in developing countries. Investments in biomass decreased in all countries, while marine energy investments increased everywhere. According to Bloomberg New Energy Finance, the financing of large hydropower projects commissioned in 2014 was about 31 billion dollars (Renewables, 2015; Bloomberg New Energy Finance Report, 2015).

RENEWABLE RESOURCES FOR UKRAINE: SWOT – ANALYSES AND PROSPECTIVE SCENARIO

Assessing the energy dependence of the country and the current state of the energy sector of Ukraine, we primarily analyze the volumes of domestic levels in simultaneous comparison with world indicators (Annex 2). All considered trends support the only conclusion – Ukraine is weak in the energy production and not comparable with world leaders in the energy sector. The state is deeply energy-import dependent, so cannot be for now ambitious energy player on the global energy scene.

STRENGHTS. The ranking representation (Table 1) shows that being in the lower segment of world rankings on aspects of energy security; Ukraine shows positive tendencies to the improvement, however with slow steps. So, it pushes the idea that Ukraine does not need any levers for the choosing direction on the improvement, but has a deficit of mechanisms to stimulate and accelerate positive trends. Such mechanisms are renewable resources and an effective usage of internal capacities of state energy security.

In Ukraine the share of energy extracted from renewable sources is about 6% in 2014 (according to the State Statistics Committee of Ukraine). According to the Ukrainian energy strategy to 2030, the share of alternative energy in the overall energy balance of the country should increase up to 20%.

Due to the high price of electricity produced from RES Ukraine implemented "green tariff", the economic mechanism aimed at promoting renewable energy power generation.

Table 1

Dynamics of energetic performance of Ukraine in 2000–2014

Climate and Energy	Access to Electricity	EPI	Energy Trilemma Index	Energy Security	Energy Equity	Energy Security Risk
0	↑	↑	↑	↑	0	↓

(↓ - Deteriorated, ↑- Improved, 0 - No change)

Source: authors' compilation based on Energy 2020; World Energy Council; World Development Indicators; International Energy Agency.

WEAKNESSES. However, despite the significant amount of laws, programs, regulations and other documents the dealing with implementation of RES in the country is too slow; the contribution to the energy balance of the country is quite small and actually decreased last year from 8 to 6%.

Lacking in cooperation between political authorities and enterprises, weak involvement of private sector in most fore of energy policy coordination boosted with the strained budget situation in the country makes the RES implementation the question of the far future, thus increasing the state's dependency on Russia.

Low public acceptance of wind energy, and, accordingly, no large wind power plants as well as no instruments to counter socioeconomic split in affordability of both RE-installation and EE-measures make all slight efforts of government as unpopular.

No national grid for RES makes the RES consumption possible only in the place of its production, and decrease the diversity of RES over the country.

OPPORTUNITIES. Wind energy is currently the most advanced type of RES in Ukraine. Ukraine has its own advent of wind turbines (windmills) and its licensing. There are eight wind power plants (WPP) in the Crimea, the Azov Sea and the Carpathian region. Since 1997, when adopted comprehensive program of building wind plants, wind power in Ukraine received state support in the form of bonuses to the electricity tariffs and direct funding.

Bio-energy in Ukraine has a wide range of raw materials that can be used both by direct combustion and biogas, biodiesel, ethanol, solid fuel pellets and others. In addition to raw materials, in Ukraine there is technology and industrial base for industrial development of biodiesel, bio-ethanol, bio-gas. However, there are just individual examples of the construction of plants for bio-fuel production, development of new processing technologies bio-sources. There are no technical specifications and regulations on the production, storage and use of bio-fuel, thus any conditions for attracting investments in the construction of appropriate factories.

Solar energy in Ukraine used at present only for hot water heating (using solar collectors and electricity from photovoltaic cells). Solar collectors manufactured by enterprises of Ukraine, the domestic photovoltaic installations are just beginning to enter the market, although there is an urgent need for raw materials at a reasonable price. There is the extreme necessity in government support to revive the country's current production capacity of solar silicon (previously 10% of world productions were in Ukraine). The climatic conditions of Ukraine, especially in southern regions, can support solar energy production.

Geothermal energy is an exceptionally promising source of energy for Ukraine. The most favourable conditions for the use of geothermal waters exist in the Crimea (Tarkhankut and Kerch peninsula) and in the Carpathian region. But even in these areas, less than 2% of capacity is produced. Geothermal water can be used for heating and hot water. Ukraine has powerful resources of small hydropower - about 63 thousand small rivers, the potential of which is up to 28% of the total hydro-potential of Ukraine.

After analyzing the current situation with RES, the history of electricity trend since Ukraine's independence shown (Fig. 2) that the volume of electricity production fell from nearly 300 billion kWh in 1990, reaching a peak in the fall of 2000 - 160 billion (excluding the decline in production in 2009 and now low production rate). There is still some rising seen in recent years.

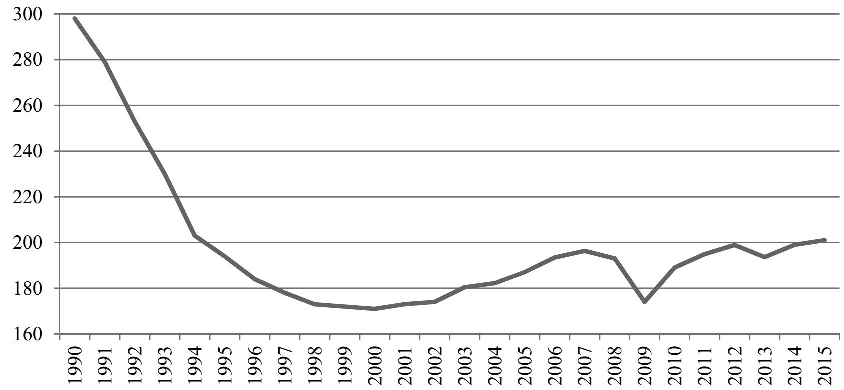

Figure 2. Electricity production since the independence of Ukraine (billion kWh)

Source: the State Statistics Committee of Ukraine; International Energy Statistics.

Compare the percentage of renewable energy sources change in the total output (Fig. 2) and separately wind power and solar (Fig. 3).

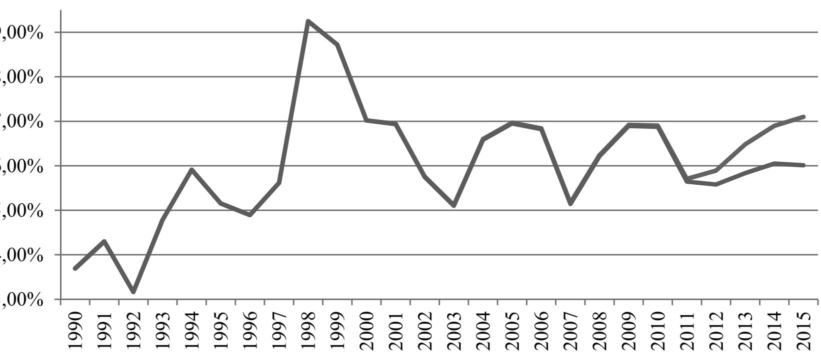

Fig. 3. The share of renewable energy in electricity production in Ukraine (blue line - % of RES; red line - % of hydroenergy)

Source: the State Statistics Committee of Ukraine; International Energy Statistics.

As shown in Fig. 3, the share of wind energy compared with the percentage that is produced at power stations is extremely small, so the graphics and the share of renewable and hydroelectricity are imposed. This trend traced by 2011. Then after the discovery of new wind farms and SES percentage increased almost three times. But both lines tend to increase. This is due to the obligations Ukraine gave to the EU to support the growing share of renewable energy in total output to 20% already in 2020, and with multimillion investments in this area.

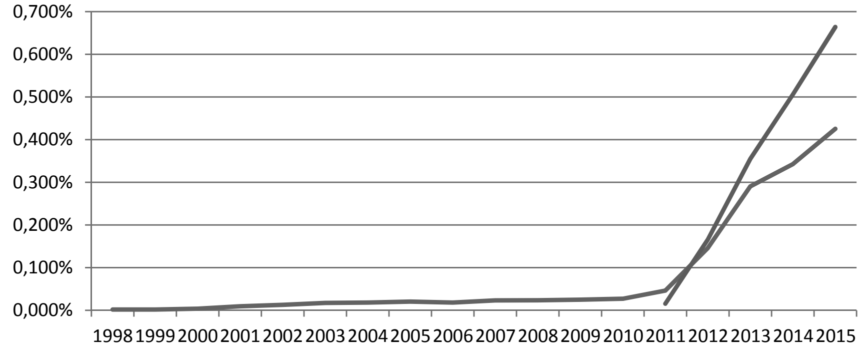

Fig. 4. The percentage change of wind and SES energy in electricity output in Ukraine (blue line – wind RES, red line – SES)

Source: the State Statistics Committee of Ukraine; International Energy Statistics.

Wind energy in Ukraine was implemented in 1998 (the first wind farm in Tarkhankout Peninsula). By 2011, the share of small wind farms growing rapidly, but then - after new capacity launching output volumes grew significantly (Fig. 4).

As we can see, the share of wind and solar energy in the total output tends to increase. During the last year the absolute gain used to be: ΔWRES = 0,272 × 109 kWh, and ΔSES = 0,357 × 109 kWh, and growth rates T_{WRES} = 1.94 and T_{SES} = 2.08 respectively. This is most clearly stands out against the backdrop of recession in manufacturing of all kinds of energy production.

As to hydro-RES the volumes of production almost unchanged.

From policy view, unlocking the synergies between urban systems opens up a wealth of benefits – environmental, social and economic. Encouraging multi and trans-disciplinary cooperation between stakeholders like communities, municipalities, regional and national governments, institutes and universities, civil society organizations and private companies, can achieve remarkable results in their cultural context by working together /networking across boundaries to create better cities, to identify practical and integrated systems solutions.

Developing visions, scenarios, strategies and solutions for sustainable urban development and renewables applications could be a new focus for energy policy in EU.

Urban resilience represents the durable ability of municipalities to take action, while continuing to transform and develop. In a time of amplified preoccupations on ecological and social structure, comprehending how to strengthen such systems is indispensable. Urban resilience to the impacts of climate change includes health and safety aspects, food security and energy provision. It must be related to the larger circumstance of the adjacent neighbourhood (local, national and global interdependencies), including the provision of vital resources as water, food, energy resources, labour, capital and functional markets.

An integrated approach to urban development will identify contrary policies and consider alternative development scenarios at an early stage in planning processes, and involve stakeholders in balancing different objectives to achieve solutions that best combine *ecological, socio-cultural, economic and spatial* considerations.

Awareness rising is the starting point for participation and the quality of urban planning processes and their outcomes is significantly affected by the degree of openness and participation. For example, both producers and consumers need to be informed about environmental problems and engaged in solutions.

THREATS.

Occasionally arbitrary and lengthy approval procedures for (small) wind energy and water plant. The main constraint on the development of wind energy in Ukraine is the low technical and economic efficiency of wind turbines, which does not allow it to compete on equal terms with traditional forms of energy. The way to achieve higher performance - is to increase unit capacity of wind turbines to the megawatt class, attracting private capital to invest in wind power industry. This will facilitate the introduction of so-called "green" tariff.

– Lack of coordination between regions, Ukraine and its partners (the EU through EaP).
– Low feed-in-tariffs for wind energy
– Global financial crisis potentially affecting power plant operators via credit requirements, war-conflict in the East, high risks for potential investors.
– The Crimean crisis and the continuing instability in Eastern Ukraine have turned into a rude wake up call for Ukraine, and the whole Europe's energy security vulnerabilities (Vladimirov, 2015; CSD Policy Brief No. 47: EU and NATO's role in tackling energy security and state capture risks in Europe).

EVALUATING THE EFFECTIVENESS OF THE RES IMPLEMENTATION IN UKRAINE: EMPIRICAL RESULTS

The definition of renewable energy sources implies that to maintain its production there is no need in raw materials and, consequently, recycling of wastes. Therefore, most of the indicators used to determine the effectiveness of innovation and new technologies in production are not quite fit to assess issues with RES. However, it is possible to use a system of indicators of technological, economic, social and ecological performance (Annex 1).

Process (technological) efficiency is characterized by complex of physical and cost indicators that reflect the degree of land usage, labour, material resources in the production of electricity: absolute growth rates and general public production; output increase of each type of alternative energy sources; the total percentage of RES. Social efficiency involves improving of living conditions, the degree of social development, include wages and profit per employee. Environmental efficiency is regarded as preserving the environmental situation with the growth of productivity and the provision of clean energy. Environmental efficiency is determined by a reduction of environmental pollution, and other non-waste production. Since RES do not carry the pollution itself. The criterion of economic efficiency is the growth of labour productivity. Renewable energy consumption (% of total final energy consumption) and Renewable electricity output (% of total electricity output) are considered as the result, dependent variables.

This table could be as well considered as a calculative basis for SWOT – analyses of RES. By means of correlation analyses implementation (ⱹ=0,1) we could arrange set of factors that has tight correlation with Renewable energy consumption (% of total final energy consumption) and Renewable electricity output (% of total electricity output) – see figures in parenthesis, correspondingly (Annex 1). These are selected factors which ρ > ±0.7 showing high dependency. Data set is 1990-2014 annual performance.

We received such evidence on the base of correlation analyses for the considered period in Ukraine:

1. RES production has a potential to replace oil, gas and coal sources, however not same could be said about nuclear power;
2. RES production opens new projects in industry thus the employment rate in industry can grow, but not such could be said about agriculture;
3. In recent years RES production had quite low level of impact on the economic performance;
4. RES have positive effect on the environment in Ukraine in analyzed period;
5. RES consumption has a potential to boost positive effects of alternative energy resources, more than even its production. That evokes the idea of necessity to implement policy and some actions to motivate namely private consumers and industry to increase the consumption of RES. Then it could motor the increase of RES production, obviously.

Renewable energy consumption and production (% to total energy volumes) in Ukraine has positive correlation (61%) in 1990-2014 period. That is positive but still low level. Means that increasing part of RES in total energy production not fully be reflected in increasing of it consumption. That mostly indicates quite resistance of population and industry to use RES power capacities.

Having the results of correlation analyses, we step in further statistical performance for most significant indicators (1990-2014, Ukraine): despite the assembling of Annex 1 on the correlation matrix analogue, we do not consider the direction of impact, as it is unclear in the capacity of correlation analyses. As a correlation coefficient just shows us the density and effective communication between factor variables for their linear dependence. By means of correlation we can detect only strong interdependence in time series of representative indexes but cannot deep in the nature of such dependency. The direction of the dependency stays unclear. The causes preceding the correlation, if any, may be indirect and unknown. High correlations also overlap with identity relations (tautologies), where no causal process exists. For depicting the main causes and sequences in tendencies in the analyses we propose to use the Granger causality test. We pushed off the following assumptions that the correlation does not necessarily imply causation in any meaningful sense of that word. The econometric graveyard is full of magnificent correlations, which are simply spurious or meaningless. The Granger approach (1969) to the question of whether X (independent variable) causes Y (depended variable) is to see how much of the current Y can be explained by past values of Y and then to see whether adding lagged values of X can improve the explanation (Green, 1993). This approach helps us to understand what the main development indicator and of what state can cause the integration/development tendencies and can be the best indicator of its happening. Before application Granger test we clarified each of the time-series to determine their order of integration - involved a test (such as the ADF test) for which the null hypothesis is non-stationarity. Implementation of Granger causality test in EViews provided us with such resulting claims (at the appropriate level of F-stat) about link directions for considered data and states (Annex 3,4): we cannot reject the hypothesis that all performance indicators does not Granger cause RESCONSUME and we do not reject the hypothesis that RESCONSUME does not Granger cause the indicators (for all analyzed indicators). Therefore it appears that Granger causality runs both way for RES consumption (% of total final energy consumption) and most significant performance indicators of Ukraine. This means that RES are flexible to the internal situation in the country, and their positive effect can be easily absorbed inside of the country.

Taking into account the economic, social, technological and environmental performance in the long term will provide the best results in RES usage and help improve the production environment and supports energy security. To assess the effectiveness of these facilities, the thorough analyses of thematic literature (Kharlamova & Nesterenko, 2015; Chernyak & Slushaienko, 2014) let us suggest a system of indicators of four types of efficiency (Fig. 5).

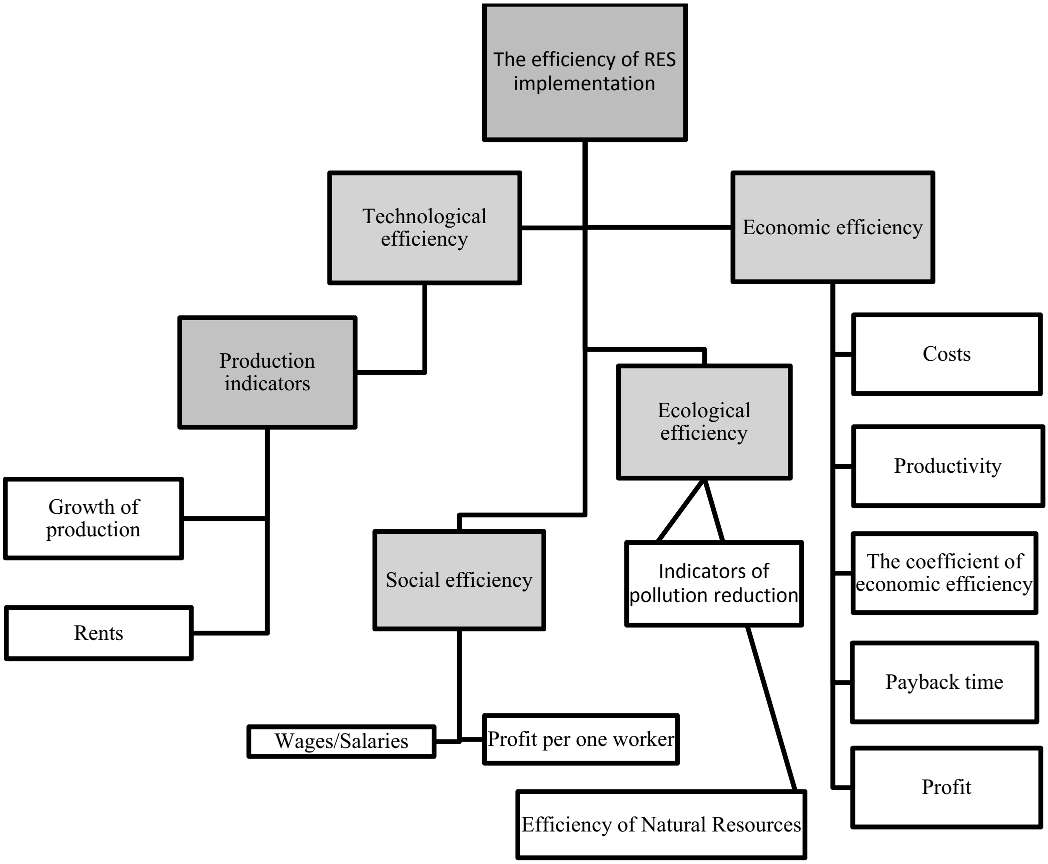

Figure 5. The system of indicators to determine the efficiency of RES implementation
Source: Compiled by authors.

To assess the effectiveness of the implementation of RES over the last few years in Ukraine, we step to calculate the power of plants in view of different RES per year. (Fig. 6).

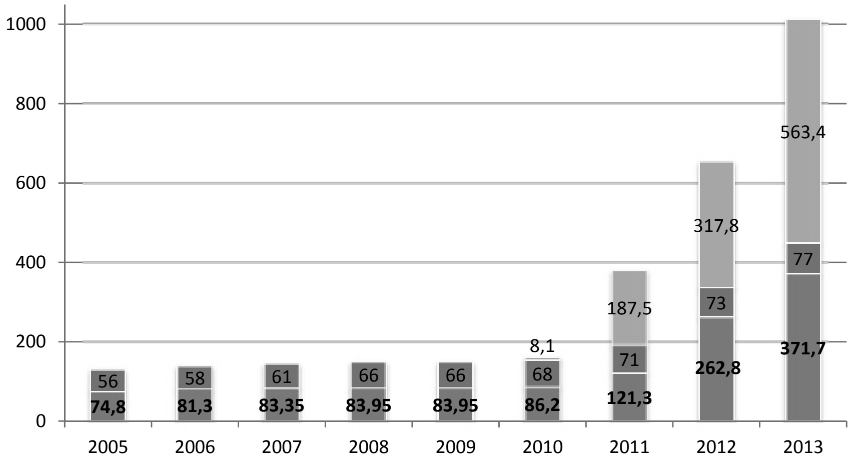

Fig. 6. Power of energy plants for 2005-2013, MW (blue – wind RES plants, red – small hydro-energy plants, and green – SES plants)

Source: the State Statistics Committee of Ukraine; International Energy Statistics

As for large hydro-energy plants the capacity has not amended per year, we do not take it in account. Indicator of absolute capacity growth of each type of RES plant is shown below:

$$\Delta WRES_{2013} = 371.7 - 262.8 = 108.9 \text{ MW}$$

$$\Delta SES_{2013} = 563.4 - 317.8 = 245.6 \text{ MW}$$

$$\Delta smallHRES_{2013} = 77 - 73 = 4 \text{ MW}$$

We intentionally stop on 2013, as from 2014 Ukraine is in conflict period, Crimea was invaded by the neighbour state, thus assessments of 2014-2015 are quite fragile if so. Table 1 shows data on the average cost of building of power plants of various types with 1MW capacity, the purchase price of 1 kWh of electricity and others.

Table 3

Basic economic characteristics in view of all types of RES plants

Type of RES plant	Wind	Solar	Hydro
Price of construction of 1 MW capacity, mln UAH	15	18	12
the “green tariff” coefficient	2,1	3,6	1,6
Realization Price of 1 kWh of electricity, kop. (Coefficient × 58,46 kop. / KWh)	122,77	210,4	93,54
Total number of employees	433	500	12
The average salary, UAH	7300	6400	7500
Full capacity hours	600	2200	1314
Total working hours	6000	2200	8760
Area, ha	142	500	-

Service life, years	25	40	80

Source: Calculated by the authors on the base of indicators from Donuzlavska and Botiyevska WRES plants, Sambor and Ohotnivska SES plants, Ladyzhyn and Hlybochatska HRES plants.

According to the technological features, wind power can work only when the wind speed is more than 3 m/s. Ukraine's average number of appropriate days is 240-260 days a year. However, the full power of wind plants can be only 10% of the time. The rest of time there is just 80% capacity in average.

Solar power plants work at full capacity only in sunny hours. On average, there is entire 2100-2300 such hours a year in Ukraine.

Hydroelectric power plants that run on "green tariff" have the right to work round the clock. But because of the volatility of the water regime even on mountain rivers, hydroelectric power plants operate at full capacity about 15% of the time per year, and the rest - 70% capacity on average. However, it is worth considering as well the fact that the consumers receive only about 15% of RES electricity through various losses.

Also for next stage of calculations the indicators we specified, the following data should be accounted as the average price per hectare of land in lease in Ukraine for 1 year - 310 UAH/ha (prices of 2013). The maximum amount of power that could be produced by a new power plant a year is calculated by:

$P = \frac{E}{t}$, then $E = P \times t$, where: E – energy produced, Joules; t – work time, seconds.

Calculate the possible amount of energy produced according to Table 3:

For wind RES:

$$E_{WRES2013} = 0{,}1 \times t \times P + 0{,}9 \times t \times P \times 0{,}8 = 0{,}1 \times 216\times10^5 \text{ sec} \times 108{,}9\times10^6 \text{ W} + 0{,}9 \times 0{,}8 \times 216\times10^5 \text{ W} \times 108{,}9\times10^6 \text{ sec} = 19{,}29\times10^{14} \text{ J} = 0{,}536\times10^9 \text{ kWh}$$

For solar RES:

$$E_{SES2013} = P \times t = 245{,}6\times10^6 \text{ W} \times 792\times10^4 \text{ sec} = 19{,}45\times10^{14} \text{ J} = 0{,}54\times10^9 \text{ kWh}$$

For small hydroRES:

EsmallHRES2013 = 0,15 × t × P + 0,85 × t × P × 0,7 = 0,15 × 315,36×105 sec × 4×106 W+ 0,85 × 315,36×105 sec × 4×106 W × 0,7 = 0,94×1014 J = 0,026×109 kWt

Next it is necessary to calculate the efficiency ratio and the payback period of possible capital investments. Thus we calculate the total amount of the investment and possible profit:

– multiply the power on the cost of construction of one MW,
– the possible return (price of kW × h of electricity multiplied by the maximum possible amount of energy, calculated above) deduct on the full costs.

$$K_{WRES} = 108{,}9 \text{ MW} \times 15000000 \text{ UAH/MW} = 1633500000 \text{ UAH.}$$

$$K_{SES} = 245{,}6 \text{ MW} \times 18000000 \text{ UAH/MW} = 4420800000 \text{ UAH.}$$

$$K_{HRES} = 4 \text{ MW} \times 12000000 \text{ UAH/MW} = 48000000 \text{ UAH.}$$

To calculate fixed costs we use the following parameters:

S - area of power plants, ha;

P - price of annual lease of 1 ha of land, UAH;

W - the average salary in power plants of this type;

n - the total number of employees;

A - amortization, calculated on a straight-line basis: the quotient of the original value of fixed assets for the period of their service. We calculate these figures for each type of RES power plant:

$$A_{WRES} = K_{WRES}/T_{WRES} = 1633500000 \text{ UAH} / 25 = 65340000 \text{ UAH}$$

$$A_{SES} = K_{SES}/T_{SES} = 4420800000 \text{ UAH} / 40 = 110520000 \text{ UAH}$$

$$A_{smallHRES} = K_{smallHRES}/T_{smallHRES} = 48000000 \text{ UAH} / 20 = 600000 \text{ UAH}$$

Now fixed costs can be counted as:

$$FC_{WRES} = S \times P + W \times n \times 12 + A = 142 \text{ ha} \times 310 \text{ UAH/ha} + 6200 \text{ UAH} \times 433 \times 12 + 65340000 \text{ UAH} = 103314820 \text{ UAH}$$

$$FC_{SES} = S \times P + W \times n \times 12 + A = 500 \text{ ha} \times 310 \text{ UAH/ha} + 6400 \text{ UAH} \times 500 \times 12 + 110520000 \text{ UAH} = 149075000 \text{ UAH}$$

$$FC_{smallHRES} = S \times P + W \times n \times 12 + A = 7500 \text{ UAH} \times 12 \times 12 + 600000 \text{ UAH} = 1680000 \text{ UAH}$$

Now we calculate the level of efficiency for investments as cost-effectiveness ratio of capital expenditure:

$$EI = (P \times Q - FC) / K.$$

For wind RES:

$$EI_{WRES2013} = (0{,}536 \times 10^9 \text{ kWh} \times 1{,}228 \text{ UAH/kWh} - 37974820 \text{ UAH}) / 1633500000 \text{ UAH} = 619812107{,}60 \text{ UAH} / 1633500000 \text{ UAH} = 0{,}379.$$

Then, $T_{payback\ WRES} = 1/E_{WRES} = 2{,}635$ year.

For solar RES:

$$EI_{SES2013} = (0{,}54 \times 10^9 \text{ kWh} \times 2{,}104 \text{ UAH/kWh} - 38555000 \text{ UAH}) / 4420800000 \text{ UAH} = 1098278280 \text{ UAH} / 4420800000 \text{ UAH} = 0{,}248.$$

Then, $T_{payback\ SES} = 1/E_{SES} = 4{,}025$ year.

For small hydroRES:

$$EI_{smallHRES2013} = (0{,}026 \times 10^9 \text{ kWh} \times 0{,}935 \text{ UAH/kWh} - 1680000 \text{ UAH}) / 48000000 \text{ UAH} = 22727988{,}00 \text{ UAH} / 48000000 \text{ UAH} = 0{,}473.$$

Then, $T_{payback\ smallHRES} = 1/E_{smallHRES} = 2{,}112$ year.

As for all type of RES plants EI>0,15, then with this first look assessments we proved the hypothesis that investing in RES plants in Ukraine has sence and can be profitable (base on 2013 price level).

However, all calcualtions above considered option of "green tarrif". Thus it seems obvious to make calculations in regime of the absence of the "green tariff", and the price is considered as average purchasing for other types of power. It is calculated as a weighted average purchasing price for thermal, nuclear and large hydro-power plants, thus the price of each type will be multiplied by the share of output for the year, products will be sum up, and the sum will be divided by 100.

$$P_{av} = (P_{thermal} \times w_{thermal} + P_{nuclear} \times w_{nucler} + P_{hydro} \times w_{hydro})/100 = $$
$$(54{,}6 \text{ kop/kWh} \times 0{,}475 + 21{,}03 \text{ kop/kWh} \times 0{,}4601 + 19{,}31 \text{ kop/kWh} \times 0{,}0587)/100 =$$
$$0{,}367 \text{ kop/kWh}$$

Calculations of cost-effectiveness ratios, annual earnings and payback periods without the use of the "green tariff" are the following:

For wind RES:

$$EI^1_{WRES2013} = (0{,}536\times10^9 \text{ kWh} \times 0{,}367 \text{ UAH/kWh} - 37974820 \text{ UAH}) / 1633500000 \text{ UAH} =$$
$$158659376 \text{ UAH}/ 1633500000 \text{ UAH} = 0{,}097.$$
$$\text{Thus, } T^1_{payback\ BEC} = 1/E^1_{WRES} = 10{,}3 \text{ year.}$$

For solar RES:

$$EI^1_{SES2013} = (0{,}54\times10^9 \text{ kWh} \times 0{,}367 \text{ UAH/kWh} - 38555000 \text{ UAH}) /4420800000 \text{ UAH} =$$
$$159742440 \text{ UAH} /4420800000 \text{ UAH} = 0{,}036.$$
$$\text{Hence, } T^1_{payback\ SES} = 1/E^1_{SES} = 27{,}67 \text{ year.}$$

For small hydroRES:

$$EI^1_{smallHRES2013} = (0{,}026\times10^9 \text{ kWh} \times 0{,}367 \text{ UAH/kWh} - 1680000 \text{ UAH}) /48000000 \text{ UAH}$$
$$= 7900461{,}6 \text{ UAH} / 48000000 \text{ UAH} = 0{,}161.$$
$$\text{Therefore, } T^1_{payback\ smallHRES} = 1/E^1_{smallHRES} = 6{,}08 \text{ year.}$$

Thus, we received that effectiveness coefficients for solar and wind power is less than 0.15, and therefore the investing in such projects at an average price, ie without the use of the "green tariff" stimulating policy of Ukriane, would be inappropriate. Thus, we regect the hypothesis that the alternative resources in Ukraine are interesting for the investing and implementation without any smart governement policy of stimulatng. A similar ratio for small hydropower plants close to the base, so even at this purchasing price investments in hydropower in Ukraine could be appropriate.

Thus, we recieved the important conclusion that the "green tariff" indeed makes RES projects more attractive for investments.

For more ground conclusions calculate such indicators as self-cost (S), productivity (L) and the amount of earnings per employee (M) for each type of RES power plant. Quite obviously the productivity is calculated as the quotient power produced per year in kWh on the number of employees. Self-cost is the ratio of all costs of production and the quantity of production. Calculate and compare these figures with the cost of other forms of power that is $S_{nuclear} = 0{,}05$ UAH/kWh , $S_{thermal} = 0{,}14$ UAH/kWh.

	wind RES	solar RES	small hydroRES
Productivity (L)	$L_{WRES2013} = E_{WRES2013}/n =$ $0{,}536\times10^9$ kWh / 433 = 1237385,68 kWh per capita	$L_{SES2013} = E_{SES2013}/n =$ $0{,}54\times10^9$ kWh / 500= 1080640 kWh per capita	$L_{smallHRES\ 2013} = E_{smallHRES\ 2013}$ $/n = 0{,}026\times10^9$ kWh / 12 = 2175400 kWh per capita

Amount of earnings per employee (M)	$M_{WRES2013} = TR_{WRES2013}/n =$ 619812107,60 UAH / 433 = 1431436,74 UAH per capita	$M_{SES2013} = TR_{SES2013}/n =$ 1098278280 UAH / 500= 2196556,56 UAH per capita	$M_{smallHRES\ 2013} = TR_{smallHRES\ 2013}$ / n = 22727988 UAH / 12 = 1893999 UAH per capita
Self-cost (S)	$S_{WRES2013} = FC_{WRES2013}/ E_{WRES2013}$ = 103314820 UAH / $0{,}536\times10^9$kWh= 0,0709 UAH/ kWh	$S_{SES2013} = FC_{SES2013} / E_{SES2013} =$ 149075000 UAH / $0{,}54\times10^9$ kWh = 0,0714 UAH/kWh	S smallHRES 2013 = FC smallHRES 2013 / E smallHRES 2013 = 1680000 UAH / 0,026×109 kWh = 0,0644 UAH/kWh

Quite seen that self-cost for thermal power plant performance are superior to similar data for RES power plants. This is because thermal power plants need extra fuel costs and its utilization. Similar figures for nuclear power plants are lower. This is due to lower gross costs, greater efficiency, compared to thermal power plants, as well as the possibility of continuous operation at full capacity. In terms of productivity and self-cost, the leading is hydropower among RES, but as to the profit per employee it is higher in SES. High productivity and low costs on small hydropower plants are associated with their small production capacity and a small number of employees.

The maximum possible annual electricity production of all types of renewable energy that were implemented in 2013 is $1{,}102 \times 10^9$KWh. Since the thermal power plant to generate 1 kWh requires 0.5 kg of coal, then new capacity in renewable energy allows saving more than 5.5 mln. tons of coal and reduce emissions by nearly 16,000 tons per year.

CONCLUSIONS AND DISCUSSION

This research has an important political component, because Ukraine is trying to integrate its economy into the EU. Further expansion of international economic cooperation requires the implementation of energy policy, which would be a coherent policy of leading countries, especially the European Community. Another and perhaps the most important aspect is the energy dependence of Ukraine. And one of the outputs of this situation is seen in the development of alternative energy sources (RES).

However, the question remains insufficiently illuminated on the reasons for the low rate of implementation of non-conventional renewable energy sources, assess of its effectiveness and identification of the most appropriate RES for Ukraine.

Conducted calculations proved (on the base of pre-war 2013 year) that there is the sense and possibility of profit in investing in RES power projects in Ukraine, however mostly in regards to existence of “green tariff”.

Having analysed the economic, social, technological and environmental performance of RES in Ukraine, it can be concluded that the policy implementation of alternative energy in Ukraine could be still effective. First of all it is not scattered from the world. Second, the state creates adequate conditions for investments in this area. As well the power capacity, the percentage of electricity generated and annual production volumes for this type of power is growing from year to year. And as the technology is not standing still, thus new technologies in the field of renewable energy in the future will make investments in these projects profitable without the use of the “green tariff” in Ukraine.

Results of statistical analyses should encourage more deep consideration of energy security of Ukraine at the local level: there is a need in evolution and “Ukrainian” meaning of energy security – the state should come out step by step from state to regional and local concern about RES. In aspect of RES, it is to be assumed that the importance of local energy security will grow in the future, as a result of consistent implementation of administrative reforms, involving i.e. delegation of powers of central government to provinces, districts and municipalities. Before entry to the EU and being member of EaP Ukraine should consider the following aspects of energy security in three different administrative dimensions:

1. National: creating conditions for the unhindered development of the infrastructure of international, inter and intra regional links (especially for RES), enabling reliable and unlimited provision of transit, transmission and regional RES energy distribution;
2. Regional: boosting the ability and willingness of industries and private consumers to provide energy transmission services for municipalities and energy exchange as to RES production and consumption;
3. Local: insuring the reliability and continuity of supply of RES energy.

Thus, based on the evidence of just positive effects even small volumes of RES implemented Ukrainian energy security should consider the diversification of energy supplies not only as external issue but as well as internal (RES). To ensure certainty of supply at an acceptable for society and the economy price the government should keep "green tariff", simplify the nationwide administrative procedures but also propose manuals for consideration of the optimum utilization of domestic energy resources, while applying new technologies and active participation in international initiatives on environment and energy. Ukraine should strive to take into account the specificity of prepared solutions of the Ukrainian economy thus the shift from oil-gas scenario to gas-RES scenario.

In order to articulate the energy strategy and policy at the European level, an analysis of communities' energy development potential, as well as the feasibility and urban design components must be financed first through EU or EaP programs. In this sense, there is a need of a methodological framework at the national level, based on variables and predetermined development indicators for monitoring and evaluation of energy projects. Ideally, it should encourage greater autonomy of the municipalities and regional administrations, consequently leading to a synergic compatibility of local development needs with their strategic aspirations, without a noticeable interference with multiple bureaucratic and hierarchical obstacles at the national level. Thus, a redistribution of prerogatives towards local governments and citizens through an adjustment of the national legislation would facilitate a proper implementation of energy projects.

Creating conditions for the development of standard implementations procedures at the European and national levels, debates focused on the convergence of local projects and their integration into the national and European level should become the main objective during the implementation of local energy projects. This step becomes more effective once the growth and development of social infrastructure for energy is stimulated through identifying a co-interest between the citizens, the public sector, academic and business environment. It is recommended to identify a clear set of steps to access the benefits and responsibilities/liabilities of the actors involved, both providers and recipients of energy. The development of a manual of good practices for the development of energy efficient communities should ensure the convergence of future strategies, policies, tools, procedures and results at the national and EU/EaP level.

In order to provide short-term (1-2 years) energy security and rational exploitation of the environment, the national government along with the EaP programmes must be engaged in an effort to ensure de-bureaucratization and decentralization of energy policies in order to support specific implementation of models/local projects for future sustainable bio-communities.

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Annex 1

World Bank indicators available (63) to perform RES in efficiency coordinates: case of Ukraine

Indicators of technological performance	Indicators of economic performance
1	2
– Access to electricity (% of population) (0.99/ 0.73) – Alternative and nuclear energy (% of total energy use) (0.83 / 0.73) – Electric power transmission and distribution losses (% of output) (- 0.03 / 0.63) – Electricity production from hydroelectric sources (% of total) (0.54 / 0.99) – Electricity production from nuclear sources (% of total) (0.67 / 0.83) – Electricity production from oil, gas and coal sources (% of total) (- 0.68 / -0.87) – Electricity production from renewable sources, excluding hydroelectric (kWh) (0.69 / 0.71) – Energy intensity level of primary energy (MJ/$ 2011 PPP GDP) (0.53 / 0.15) – Energy use (kg of oil equivalent per capita) (0.70 / 0.83) – Access to non-solid fuel (% of population) (0.93 / 0.83) – Combustible renewables and waste (% of total energy) (0.98 / 0.45) – Electric power consumption (kWh per capita) (0.34 / 0.84) – Electricity production from coal sources (% of total) (-0.50 / -0.31) – Electricity production from natural gas sources (% of total) (-0.95 / -0.48) – Electricity production from oil sources (% of total) (-0.65 / -0.80) – Electricity production from renewable sources, excluding hydroelectric (% of total) (0.71 / 0.73) – Energy imports, net (% of energy use) (-0.83 / - 0.38)	– Coal rents (% of GDP) (- 0.59 / -0.12) – Expense (% of GDP) (0.86 / 0.07) – GDP per capita growth (annual %) (0.17 / 0.14) – GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent) (0.78 / 0.20) – GNI per capita growth (annual %) (0.57 / 0.38) – Industry, value added (% of GDP) (0.93 / 0.45) – Natural gas rents (% of GDP) (-0.43 / 0.32) – Oil rents (% of GDP) (-0.24 / 0.48) – Research and development expenditure (% of GDP) (0.72 / 0.47) – GDP growth (annual %) (0.16 / 0.11) – GNI growth (annual %) (0.55 / 0.39) – Gross national expenditure (% of GDP) (-0.55 / -0.15) – Manufacturing, value added (% of GDP) (0.68 / 0.04) – Mineral rents (% of GDP) (- 0.62 / 0.31) – Total natural resources rents (% of GDP) (-0.42 / -0.26)

1	2
– Employment in agriculture (% of total employment) (-0.19 / 0.09) – Employers, total (% of employment) (-0.42 / -0.45) – Employment in industry (% of total employment) (0.80 / 0.77) – Employment to population ratio, 15+, total (%) (modelled ILO estimate) (-0.46 / -0.47) – Population growth (annual %) (0.06 / 0.39) – Wage and salaried workers, total (% of total employed) (0.55 / 0.36)	– Agricultural nitrous oxide emissions (% of total) (-0.87 / -0.84) – CO_2 emissions from electricity and heat production, total (% of total fuel combustion) (-0.17 / -0.46) – CO_2 emissions from liquid fuel consumption (kt) (-0.37 / -0.19) – CO_2 emissions from gaseous fuel consumption (kt) (-0.75 / -0.03) – CO_2 emissions from other sectors, excluding residential buildings and commercial and public services (% of total fuel combustion) (-0.54 / -0.81) – CO_2 emissions from solid fuel consumption (% of total) (-0.22 / -0.32) – GHG net emissions/removals by LUCF (Mt of CO_2 equivalent) (- 0.98 / - 0.77) – Methane emissions in energy sector (thousand metric tons of CO_2 equivalent) (-0.99 / -0.75) – Nitrous oxide emissions in energy sector (thousand metric tons of CO_2 equivalent) (-0.67 / -0.98) – PFC gas emissions (thousand metric tons of CO_2 equivalent) (-0.86 / -0.50) – PM2.5 air pollution, population exposed to levels exceeding WHO guideline value (% of total) (-0.52 / 0.00) – SF6 gas emissions (thousand metric tons of CO_2 equivalent) (- 0.99 / - 0.78) – Agricultural methane emissions (% of total) (-0.93 / -0.92) – CO_2 emissions from gaseous fuel consumption (% of total) (-0.60 / -0.21) – CO_2 emissions from liquid fuel consumption (% of total) (-0.69 / -0.05) – CO_2 emissions from manufacturing industries and construction (% of total fuel combustion) (- 0.64 / -0.40) – CO_2 emissions from residential buildings and commercial and public services (% of total fuel combustion) (-0.44 / -0.67) – Energy related methane emissions (% of total) (-0.89 / -0.75) – HFC gas emissions (thousand metric tons of CO_2 equivalent) (- 0.98 / - 0.68) – Industrial nitrous oxide emissions (thousand metric tons of CO_2 equivalent) (-0.74 / - 0.79) – Nitrous oxide emissions in industrial and energy processes (% of total nitrous oxide emissions) (-0.86 / - 0.79) – Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO_2 equivalent) (- 0.50 / -0.76) – PM2.5 air pollution, mean annual exposure (micrograms per cubic meter) (- 0.81 / -0.92)

Annex 2

Share of RES in power production, %

	2000	2005	2010	2011	2012	2013	2014	2000 - 2014 (%/year)
1	2	3	4	5	6	7	8	9
World	19,1	18,6	20,2	20,6	21,5	22,2	22,9	1,3
Europe	20,5	20,1	25,7	25,8	28,9	31,5	32,7	3,4
European Union	15,1	15,3	21,6	22,0	24,8	27,8	29,7	4,9
Austria	73,4	65,1	68,6	68,4	77,0	80,3	83,4	0,9
Belgium	3,6	4,7	9,6	11,9	15,9	17,1	20,3	13,1
Bulgaria	7,2	10,7	13,8	9,3	12,8	17,4	16,8	6,2
Cyprus	0,0	0,0	1,4	3,6	5,4	7,6	8,4	n.a.
Czech Rep.	3,9	4,6	7,6	9,2	10,1	11,8	12,0	8,4
Denmark	17,0	29,3	33,9	42,5	50,7	48,1	58,5	9,2
Estonia	0,2	1,1	8,1	9,1	12,3	9,6	11,9	33,4
Finland	33,5	33,5	30,2	33,2	40,9	36,4	38,4	1,0
France	13,8	10,9	14,9	12,7	15,8	18,0	17,2	1,6
Germany	7,9	11,7	18,6	22,2	24,8	26,0	28,2	9,5
Greece	8,8	11,8	18,6	14,3	17,1	25,3	25,6	8,0
Hungary	0,8	5,4	8,5	7,9	8,0	9,5	11,0	20,1
Ireland	6,2	8,5	13,7	19,7	20,0	23,0	25,5	10,6
Italy	21,0	18,7	27,3	28,8	32,2	40,1	43,8	5,4
Latvia	68,3	69,6	54,9	50,5	66,6	56,9	49,8	-2,2
Lithuania	5,6	5,6	29,0	35,0	33,7	44,1	51,9	17,2
Luxembourg	81,6	24,8	36,4	37,0	37,4	50,8	51,6	-3,2
Netherlands	4,7	8,9	10,8	12,4	14,0	13,8	12,9	7,5
Norway	99,7	99,5	95,8	96,6	98,1	97,9	97,8	-0,1
Poland	3,0	3,5	7,3	8,3	10,7	10,7	12,9	10,8
Portugal	30,9	19,2	53,8	47,7	44,3	59,8	61,9	5,1
Romania	28,5	34,0	33,9	26,6	25,7	34,8	41,7	2,8
Slovakia	16,1	15,3	22,8	18,8	20,4	23,2	22,1	2,3
Slovenia	28,7	23,7	30,0	25,1	28,7	33,5	39,5	2,3
Spain	17,2	16,1	33,7	30,8	30,7	40,0	40,5	6,3
Sweden	57,4	51,9	56,1	56,9	59,9	54,9	56,7	-0,1
United Kingdom	3,5	5,6	7,9	10,7	12,7	16,4	21,0	13,7
Albania	97,0	98,7	99,8	99,4	100,0	100,0	n.a.*	n.a.
Croatia	55,1	51,9	61,0	45,0	49,5	65,2	71,8	1,9
Iceland	99,9	99,9	100,0	100,0	100,0	100,0	100,0	0,0
Macedonia	17,2	21,5	33,5	21,2	16,7	26,1	n.a.	n.a.
Serbia	35,1	33,0	33,0	23,9	27,0	27,2	n.a.	n.a.
Switzerland	59,2	59,1	59,5	57,1	62,2	61,8	60,3	0,1
Turkey	25,0	24,6	26,4	25,4	27,3	28,9	20,8	-1,3
CIS	18,3	18,0	16,7	16,1	15,9	17,4	16,9	-0,6
Kazakhstan	14,7	11,6	9,7	9,1	8,4	8,4	8,8	-3,6
Russia	19,1	18,6	16,5	16,2	16,0	17,6	17,1	-0,8
Ukraine	6,7	6,7	7,1	5,7	5,9	8,1	6,0	-0,8
North America	15,9	15,8	17,0	19,3	19,2	19,8	19,8	1,6

1	2	3	4	5	6	7	8	9
Canada	60,6	59,6	61,7	62,5	62,8	62,8	61,9	0,2
United States	9,2	9,4	10,9	13,0	12,8	13,3	13,5	2,8
Latin America	62,0	59,3	57,6	58,1	55,7	53,0	52,2	-1,2
Argentina	33,2	33,7	28,8	26,2	24,0	24,6	25,2	-1,9
Bolivia	51,5	41,5	35,1	36,1	33,8	32,9	n.a.	n.a.
Brazil	89,5	87,1	84,7	87,1	82,5	76,8	72,9	-1,5
Chile	48,5	53,9	40,2	39,6	36,4	35,3	42,8	-0,9
Colombia	75,5	80,2	72,1	83,5	79,6	71,7	70,0	-0,5
Ecuador	71,7	55,3	45,6	55,6	54,9	48,9	n.a.	n.a.
Mexico	19,9	15,6	17,6	15,9	15,0	13,4	17,4	-1,0
Paraguay	100,0	100,0	100,0	100,0	100,0	100,0	n.a.	n.a.
Peru	82,0	72,3	57,7	56,8	55,2	52,6	n.a.	n.a.
Trinidad and Tobago	0,4	0,3	0,0	0,0	0,0	0,0	n.a.	n.a.
Uruguay	93,4	87,5	87,6	72,0	61,7	80,9	n.a.	n.a.
Asia	13,5	13,9	16,1	15,7	17,4	18,0	19,5	2,6
China	16,6	16,2	19,0	17,3	20,4	20,7	23,0	2,3
Hong-Kong	0,0	0,0	0,2	0,2	0,2	0,2	0,2	n.a.
India	13,6	16,6	16,1	17,4	15,8	16,9	15,2	0,8
Indonesia	16,0	13,6	15,9	12,0	11,4	12,0	12,0	-2,0
Japan	11,0	10,5	12,3	13,5	13,2	14,1	15,7	2,6
Nepal	98,4	99,4	99,9	99,9	99,5	99,7	n.a.	n.a.
Pakistan	25,2	33,0	33,7	30,0	31,1	31,9	32,2	1,7
Philippines	42,9	32,4	26,3	28,7	28,5	26,4	25,6	-3,6
South Korea	2,0	1,4	1,8	2,2	2,1	2,4	2,7	2,1
Sri-lanka	45,8	37,2	53,1	40,8	29,2	59,7	n.a.	n.a.
Taiwan	5,7	4,9	4,8	4,7	5,4	5,6	5,3	-0,6
Thailand	6,8	5,5	5,6	8,0	8,3	8,0	8,2	1,4
Pacific	18,8	17,9	18,5	20,2	19,3	22,3	22,2	1,2
Australia	8,5	8,9	8,6	10,1	9,7	13,1	12,1	2,5
New Zealand	71,5	64,2	73,2	76,0	71,8	74,0	79,0	0,7
Africa	17,8	16,9	17,6	17,0	16,7	17,3	18,3	0,2
Algeria	0,2	1,5	0,4	0,9	1,0	0,5	1,0	12,2
Bahrain	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Egypt	17,7	12,1	10,0	9,3	9,0	8,1	7,9	-5,6
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Morocco	6,1	8,3	18,0	11,3	9,2	14,9	n.a.	n.a.
Tunisia	0,8	1,5	1,1	1,0	1,7	2,3	n.a.	n.a.
Botswana	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cameroon	98,9	94,2	73,2	73,3	73,0	68,5	n.a.	n.a.
Congo DR	100,0	99,9	99,6	99,6	99,6	99,6	n.a.	n.a.
Ivory Coast	36,8	27,2	28,3	30,1	26,4	21,9	n.a.	n.a.
Ethiopia	98,6	99,6	99,4	99,4	99,4	99,6	n.a.	n.a.
Gabon	61,6	51,5	46,7	41,3	41,7	37,9	41,1	-2,9
Ghana	91,5	82,9	68,8	67,5	67,1	64,0	64,7	-2,4
Kenya	49,4	72,5	69,5	67,3	75,2	78,0	n.a.	n.a.
Namibia	99,2	99,8	95,6	98,2	97,8	95,6	n.a.	n.a.
Niger	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

1	2	3	4	5	6	7	8	9
Nigeria	38,2	33,0	24,4	21,8	19,7	23,6	23,9	-3,3
Senegal	3,3	12,7	10,7	10,7	9,8	9,8	n.a.	n.a.
Chad	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
South Africa	2,0	1,8	2,1	2,0	1,8	1,8	2,5	1,7
Swaziland	99,5	99,4	99,0	99,1	99,1	99,0	n.a.	n.a.
Tanzania	86,4	50,0	50,9	34,9	29,1	26,1	n.a.	n.a.
Middle-East	1,7	4,3	2,0	2,3	2,4	2,6	2,6	3,2
Iran	3,0	9,1	4,2	5,1	5,0	5,6	5,5	4,3
Israel	0,1	0,1	0,3	0,5	0,8	1,5	2,5	28,7
Jordan	0,6	0,7	0,5	0,5	0,4	0,4	n.a.	n.a.
Kuwait	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lebanon	4,6	8,4	5,3	4,9	6,8	6,6	n.a.	n.a.
Qatar	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Saudi Arabia	0,0	0,0	0,0	0,0	0,0	0,0	0,0	n.a.
Syria	12,8	12,4	5,6	7,8	10,4	12,9	n.a.	n.a.
United Arab Emirates	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

* n.a. – not available

Source : Energodata.

Annex 3

Pairwise Granger Causality Tests: (only significant results)
Sample: 1961 2013
Lags: 2

Null Hypothesis:	Prob.
INDVAD does not Granger Cause RESCONSUME	0.6315
RESCONSUME does not Granger Cause INDVAD	0.7126
EXPENDITURES does not Granger Cause RESCONSUME	0.3692
RESCONSUME does not Granger Cause EXPENDITURES	0.4318
EUSE does not Granger Cause RESCONSUME	0.9424
RESCONSUME does not Granger Cause EUSE	0.1591
EPRES does not Granger Cause RESCONSUME	0.5537
RESCONSUME does not Granger Cause EPRES	0.2893
EPOIL does not Granger Cause RESCONSUME	0.9628
RESCONSUME does not Granger Cause EPOIL	0.2840
EPNG does not Granger Cause RESCONSUME	0.3547
RESCONSUME does not Granger Cause EPNG	0.4833
EIM does not Granger Cause RESCONSUME	0.9736
RESCONSUME does not Granger Cause EIM	0.3192
CRESW does not Granger Cause RESCONSUME	0.0783
RESCONSUME does not Granger Cause CRESW	0.3260
ANE does not Granger Cause RESCONSUME	0.8814
RESCONSUME does not Granger Cause ANE	0.5460

Annex 4

The Legend for the analyses

Performance indicator	Abbreviation
Access to electricity (% of population)	AtE
Alternative and nuclear energy (% of total energy use)	ANE
Energy use (kg of oil equivalent per capita)	Euse
Access to non-solid fuel (% of population)	ANSF
Combustible renewables and waste (% of total energy)	CRESW
Electricity production from natural gas sources (% of total)	EPNG
Electricity production from oil sources (% of total)	Epoil
Electricity production from renewable sources, excluding hydroelectric (% of total)	EPRES
Energy imports, net (% of energy use)	Eim
Employment in industry (% of total employment)	EmpInd
Expense (% of GDP)	Expenditures
Industry, value added (% of GDP)	IndVAD
Methane emissions in energy sector (thousand metric tons of CO2 equivalent)	MetaneEES
Energy related methane emissions (% of total)	ERMetanE
Nitrous oxide emissions in industrial and energy processes (% of total nitrous oxide emissions)	NIEIEP
Renewable electricity output (% of total electricity output)	**RESoutput**
Renewable energy consumption (% of total final energy consumption)	RESconsume