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ACTIVATION OF THE CIRCULAR ECONOMY LEVERS IN AN ENERGY INDUSTRY

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ABSTRACT

The research includes an analysis of preconditions and features of the circular economy. Description and comparison of the linear and circular economies are shown. Drivers of the circular economy, as well as the barriers towards to implementation of circular economy business models and sustainable technology, are revealed.In the paper, the benefits associated with activating of the circular economy in the energy industry, which these take into account a subject-functional structure of the energy markets, are presented.The authors emphasize the influence of the circularity on the energy industry in the context of sustainable development achievement. Global trends in the development of the circular economy based on the experience of China, USA and the EU's members are analysed. The implementation practices of the circular economy based on nuclear fuel reprocessing by the example of France and Japan are presented. Factors hindering circular economy development in Ukraine's energy market are outlined.

Keywords: *circular economy, energy industry,decoupling, waste recycling, sustainability.*

ანოტაცია

კვლევა მოიცავს ცირკულარული ეკონომიკის წინაპირობების და თავისებურებების ანალიზს. წარმოდგენილია ხაზობრივი და ცირკულარული ეკონომიკების აღწერა და შედარება. გამოვლენილია ცირკულარული ეკონომიკის დრაივერები, ასევე ბარიერები, რომლებიც აფერხებენ მდგრადი ტექნოლოგიების და წრიული ეკონომიკური ბიზნეს-მოდელების დანერგვას. სტატიაში ენერგეტიკული ბაზრების საგნობრივ-ფუნქციონალური სტრუქტურის გათვალისწინებით განსაზღვრულია წრიული ეკონომიკის აქტივიზაციის უპირატესობები ენერგეტიკულ დარგში. ავტორების მიერ ხაზგასმულია წრიულობის გავლენა ენერგეტიკულ დარგზე მდგრადი განვითარების მიღწევის კონტექსტსი. ჩინეთის, აშშ-ს და ევროსაბჭოს გამოცდილების საფუძველზე გაანალიზებულია წრიული ეკონომიკის განვითარების გლობალური ტენდენციები. განხილულია წრიული ეკონომიკის გამოყენების პრაქტიკული მეთოდები ბირთვული საწვავის გადამუშავების გადამუშავების დროს საფრანგეთისა და იაპონიის მაგალითზე. ჩამოყალიბებულია ფაქტორები, რომლებიც აფერხებენ წრიული ეკონომიკის განვითარებას უკრაინის ენერგეტიკულ ბაზარზე.

საკვანძო სიტყვები: *ცირკულარული ეკონომიკა, ენერგეტიკა, დეკაპლინგი, ნარჩენების უტილიზირება, მდგრადობა.*

INTRODUCTION.

Increasing the negative impact of a human economic activity on the environment has led to an increase in climate change threats. At the International Summit in Rio de Janeiro in 1992, it was recognized that the global problem of society in the immediate future is the reduction of greenhouse gas emissions and the prevention of climate change. On this occasion, A. Gore [1], awarded the Nobel Prize for his contribution to climate protection, emphasized the coming of the most terrible catastrophe in the history of human civilization - a global climate crisis that deepens and quickly becomes the most dangerous phenomenon we have ever encountered. Thus, climate change is now understood as a central issue for economic prosperity and development.

Therefore, a new paradigm for industry should become a circular economy, because it aims at generating ecological, social and economic value, resulting in effec-

tiveness improving the state of the environment and even go beyond sustainability [2].

The process of consistent conceptualization of the ecological imperative in the system of economic activity is clearly visible in economic theories and studies. The problems of threatening human-induced impacts on the climate have been thoroughly studied and outlined in the Report of the World Commission on Environment and Development "Our Common Future" [3]. Great attention to these problems in their studies was given to foreign scholars such as R. Welford [4], R. Hahnel [5], M. Cato [6]. The issues of the circular economy were addressed in scholar works of P. Lacy[7], P. Ghisellini[8], F. Preston [9] and others.

Yet, despite the numerous scientific papers, there still is a need to concretize the importance of the circular economy for energy markets as a whole and their stakeholders in particular as the crucial modern imperative.

RESEARCH OBJECTIVE.

The aim of the present research is to define a concrete meaning ofthe circular economy in the energy industry for finding practical measures of minimizing the negative impact on the environment of the results of production and consumption.

According to the envisaged objective, the following tasks have to be accomplished: to examine the origins, preconditions and features of the circular economy; to outline the benefits of implementation of the circular economy for all subjects of the energy market; to investigate the role of reprocessing and recycle of used fuel as a tool of the circular economy in national energy strategies; to analyse the factors hindering circular economy development in Ukraine's energy market.

METHODOLOGY.

In the process of research on the above-mentioned problem, the following methods of research have been used: theoretical generalization, systematization and comparison – for the definition of the features of term «circular economy»; abstraction – for the identification of benefits of the circular economy, that might be received by all participants acting on different levels of the energy market; analysis and synthesis – for the research of scholar works dealing with the present topic.

1. THE ORIGINS AND PRECONDITIONS OF THE CIRCULAR ECONOMY

Securing the environmental conditions is a prerequisite for a thriving human society. Some researchers focus on the losses that are causing the global economy to impact the effects of climate change. According to the estimates of British economist N. Stern[10, p. 6], climate change losses on the planet can reach 5% of world GDP each year. But if do not take appropriate measures today, then these losses would reach 20% of GDP and after 15 years the natural environment will make only half of its current potential. At the same time, representatives of the Club of Rome, in particular, Welford [4] for some time advocated the idea of "zero economic growth" in the interests of promoting environmental protection and environmental stabilization.

However, Stern convinces the world does not need to choose between averting climate change and promoting growth and development. Changes in energy technologies and in the structure of economies have created opportunities to decouple growth from greenhouse gas emissions. Based on these positions the Stern Review is considered as the turning point after which climate change has been considered an important economic issue, in addition to being an environmental one.

Therefore, the most promising strategy for ensuring future prosperity lies in decoupling future economic growth from the rising rates of natural resource use and the environmental impacts that occur across the production-consumption continuum [11]. Decoupling has been a core concept underlying the work of the International Resource Panel more or less since its inception. Increasing human quality of life or wellbeing, or the value of economic output, while proportionately reducing both resource use («resource decoupling») and negative environmental impacts («impact decoupling») has been referred to as «double decoupling» [12].

The term describes a situation in which resource use or an environmental pressure either grows at a slower rate than the economic activity that is causing it (relative decoupling) or declines while the activity continues to grow (absolute decoupling) [13].

Environmental impacts – including climate change and pollution – cannot be effectively mitigated by focusing on emission abatement alone. The level of resource use determines the magnitude of final waste and emissions released to the environment, making resource management and efficiency key strategies for environmental protection.

A circular economy transition, to the extent that it results in lower resource extraction without an associated reduction of economic output, can result in improved resource efficiency and decoupling [14, p.9].

The overarching strategies manifest differently in terms of possible pathways depending on a country's level of natural resource endowment and its socio-economic context.

Absolute decoupling is recommended as an aim for high-income nations, with the need to lower average resource-consumption levels, distribute prosperity equally and maintain a high quality of life. Strategies toward waste prevention, high-value resource recovery, circular resource flows. Relative decoupling is a key strategy suited to developing economies and economies in transition to raise average income levels and eliminate poverty. These countries should strive to improve their resource efficiency even as their net consumption increases, until a socially acceptable quality of life is achieved. There is an opportunity to fast track sustainable development in such countries by learning from and leapfrogging traditional pathways [15].

Unlike the traditional linear "take-make-dispose" approach, the concept of the circular economy comes from the idea that waste, once adequately treated, can become a resource again, thereby forming a loop in the production-consumption chain. The circular economy seeks to respect planetary boundaries through increasing the share of renewable or recyclable resources while reducing the consumption of raw materials and energy and at the same time cutting emissions and material losses [16, p.6].

Each economic concept is characterized by its own approach to the step plan. These economic concepts differ in features and value, have their own advantages and disadvantages. Ifthe linear economy system boundariesare limited by short term, from purchase to sales, then the circular economy plays its lifecycle for a long time (Table 1).

Table 1

DESCRIPTION AND COMPARISON OF THE LINEAR AND CIRCULAR ECONOMIES

Parameters	Linear economy	Circular economy
Step plan	"Take-make-dispose"	"Reduce, Reuse & Recycle"
Features	Products are used until they are discarded and disposed of as waste.	Products are made of reused parts and materials and after discarding a product, materials are recycled.
Value	Value is created by maximizing the amount of products produced and sold.	Focused on value retention by keeping material streams as pure as possible during the complete value chain.
Emphasis	Eco-efficiency - maximizing the economic gain, which can be realized with a minimized environmental impact.	Eco-effectivity - minimizing the negative impact of the system, the focus is put on maximizing the positive impact of the system by radical innovations and system change.
System boundaries	Short term, from purchase to sales	Long term, multiple life cycles
Disadvantages	- Need for forecasting of supply risks; - dependence on raw material prices volatility; - degradation of ecosystems - non-consideration the "value" of social and environmental benefits; - lack of incentives to develop business models that focus on sustainable development; - resource dependence.	- If producers could direct their own product-waste, it may be more difficult to benefit from waste management for those in scale economy; - necessity of significant investments.
Advantages	- The sufficient experience has been gained and the material and technical base created.	- Facilitate ecosystems; - decoupling of economic growth from resource consumption; - substantial resource savings; - employment growth; - incentives for innovation; - reduction of carbon footprint; - diminishing resource dependence; - the economy grows less exposed to price fluctuations of the materials.
Related concepts	Brown economy	.Regenerative design, Performance Economy, Cradle-to-cradle, Industrial Ecology, Biomimicry, Green Economy, Blue Economy, Biobased Economy

Source: developed by the authors based on [17]

However, despite its obvious advantages, there are barriers towards to implementation of circular economy business models and sustainable technology, among which [18, p. 8-11]:

- Policies and regulations (the inadequate control systems for traceability hinder companies from reusing material or products that more than well meet the requirements of the new product).
- Economic viability (sustainable solutions often lack the economic viability to compete with more resource intensive alternatives or those using unsustainable input materials).
- Consumer preferences (a lack of acceptance for reused or recycled products among consumers who often have strong preferences towards new products made by virgin materials).
- Technology and infrastructure (the infrastructure for recycling is severely hampering the efficient use of resources in the country. Most of the recycling is performed by scavengers without access to adequate technology).

Nevertheless, according to Rizos et al [19] in recent years the circular economy has received increasing attention worldwide due to, inter alia, the recognition that security of supply of resources and resource efficiency is crucial for the prosperity of economies and businesses.

Lacy and Rutqvis[5] distinguish three fundamental drivers of the circular economy:

1. Resource constraints – because the current economy is wasteful and does not leave enough resources for all forever.

2. Technological development – because the introduction of new technologies, notably digital innovations, is making the circular economy increasingly attractive and viable for businesses.

3. Socio-economic opportunity – because decoupling constrained resources from growth not only enables inclusive growth but also empowers customers to squeeze the most value out of products and assets.

It should be noted that the transition to the circular economy encompasses all of the changes which allow different economic actors (including end-users) to continue creating value while preserving the natural capital and using increasingly fewer limited resources (whether non-renewable or renewing too slowly compared to consumption).

Moreover, compared to the linear economy, which is primarily transactional, the circular economy encourages greater collaboration between economic actors.

The motivation behind such collaboration can be:

- Economies of scale in terms of waste management. This production facility uses previously unreclaimed waste as fuel.
- The creation of new synergies between businesses for the reuse of waste products.
- Gaining customer loyalty by offering products that are better adapted to their needs.
- Larger investments that require a certain degree of partner commitment.
- An exchange of know-how: work with large companies specialising in waste management in order to benefit from their know-how and develop efficient recycling methods.
- The need to remove barriers linked to restrictive regulations or deeply ingrained consumer habits. Public-private partnerships are a powerful driver to address this challenge. Businesses improve their practices while the State simplifies and adapts corresponding regulations [20].

There are many benefits associated with activating the various levers of the circular economy, both for the environment and for economic growth. It is a process of innovation and transformation of business models, that affects all subjects of the energy market, namely regulatory authorities, energy generating companies, distribution and supplying companies, end-customers and investors (Figure 1).

Energy resources are facing important supply pressures due to limited stocks and an explosion in demand following increases in population. The first advantage of the circular economy is its capacity to limit this pressure, which otherwise leads to high costs, increased price volatility, and, in the long-run, risks of global shortages.

The circular economy transition has a positive role to play, including in the fight against climate change, and atmospheric pollution. This is the case for recycling because manufacturing recycled products rather than new products lead to fewer CO_2 emissions.

Therefore, by reducing waste at every stage of the value chain, the circular economy could play an essential role in the functioning of the energy market as a whole.

2. THE PLACE OF THE CIRCULAR ECONOMY IN NATIONAL ENERGY STRATEGIES

The circular economy provides a model which, if implemented correctly, would go much further than minimizing waste. Effective cycling of the many materials our society discards would enable us to rebuild our natural assets—soil and soil quality in particular—so crucial to continued prosperity [21, p. 14].

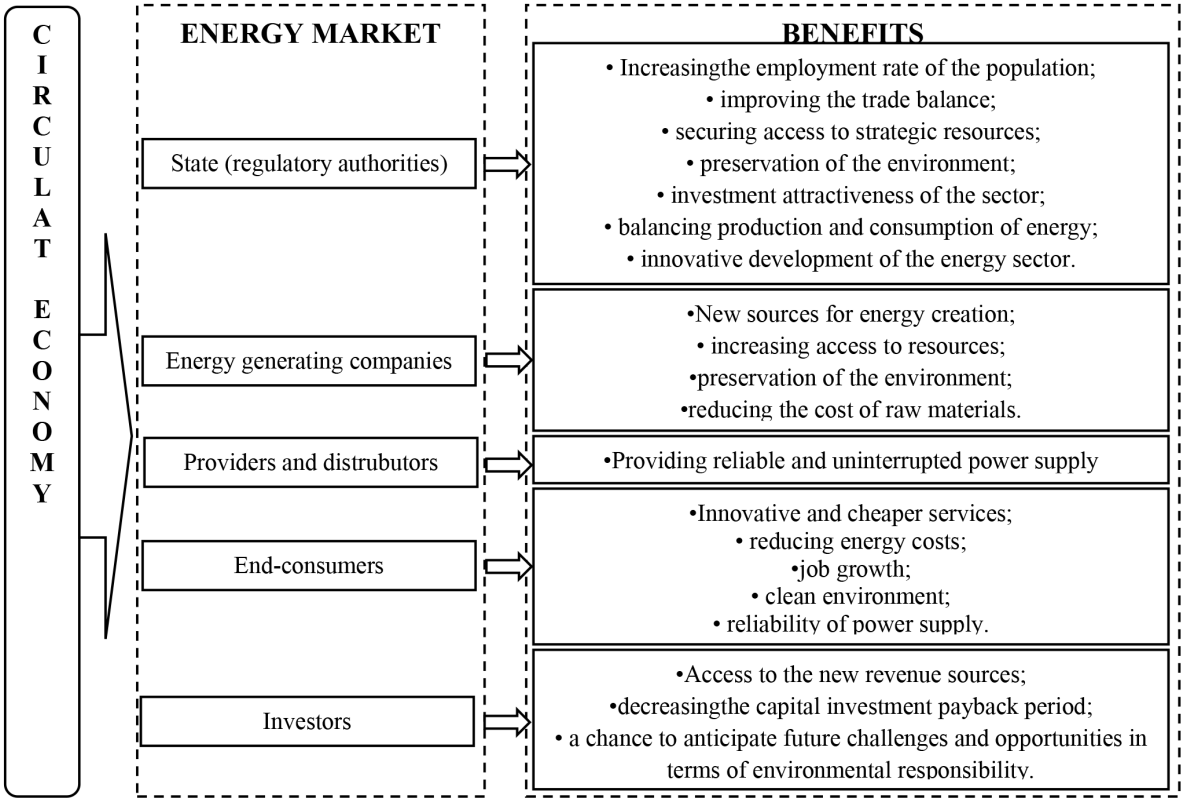

Figure 1. Benefits of the circular economy for subjects of the energy market
Source: authors' work

It should be noted that energy in thecircular economy has five active research fields [22]:

- Resources: This active fields focus on the development of production systems that utilise biomass, and consequently land, water and other resources, in efficient and sustainable ways;
- Industrial combustion and gasification processes: In this active field, the work is focused on optimisation of combustion and gasification processes – including flash pyrolysis – from the perspective of efficiency, and investment and maintenance cost, as well as emission control;
- Biochemical processes: The research within this active field is focused on developing new and existing biochemical processes that sustainably can produce products derived from biomass;
- Carbon capture processes: This active field is focused on the development of new, efficient technologies that capture and treat carbon dioxide emissions from industrial combustion processes;
- Chemical processes and process integration: The technologies and chemical processes developed within this active field will allow the energy-intensive industries to significantly increase the energy efficiency of their core processes as well as converting residual streams to high-value products.

Additionally, the increase in the use of alternative forms of energy stimulates the availability of energy for the most remote corners of the planet, increases national energy security, and minimizes the impact of climate change by reducing greenhouse gas emissions through decarbonisation of energy supplies.

At the national level, a bundle of strategies and tools is available to public authorities to support the shift towards inclusive, resource-efficient and pollution-free economies.

The Chinese government was one of the early adopters of the concept, making the transition towards the circular economy a national policy already in the 11th five-year plan. The plan intended to promote resource saving and to preserve the environment and achieve a harmonious balance of economic growth, resources as well as the population and the environment [23, p. 4].

According to International Energy Agency (IEA) statistics, China is the world leader in coal production (44.6% of world production). This, accordingly, determines coal as the main source of energy in the process of generating electricity. At the same time, the government concentrates its efforts on the development of the circular

economy at large and medium-sized enterprises in major energy-consuming industries, including electric power generation and coal mining. Thus, the regulation, which aims to stimulate the utilisation coal ash, took effect in 2013. By introducing stricter environmental policies the Chinese central government intends to reduce the environmental impact and improve the sustainability of the country's economy. China, once the world's biggest polluter, is now the world's largest backer of green energy [24].

However, in practice, only a minority of national and industry standards are mandatory; the others are voluntary standards that industry is merely encouraged to adopt. Therefore, irrespective of the content of these standards, their effectiveness is too limited to serve as a strong control to the practices of coal-fired power plants. This is one of the main reasons why it is very difficult for China to make any major headway in preventing coal ash pollution.

Within the EU, the circular economy is also gaining momentum. In December 2015, the European Commission presented an EU Action Plan for the circular economy, which addressed the whole product lifecycle from design and production through consumption and waste management. This Action Plan formed part the Circular Economy Package, which included proposals to revise key elements of the EU waste acquits: the Waste Framework Directive, the Landfill Directive, the Packaging Directive, and the Directives on end-of-life vehicles, batteries and accumulators, and waste electrical and electronic equipment (WEEE) [25].

In January 2017, the European Commission published guidelines on the role of waste to energy in the circular economy [26]: these underlined that waste to energy facilities can play a positive role. EU waste policy aims to ensure that waste is used wherever possible as raw material to make new products. Recycling is important for EU members because they are dependent on imports of scarce raw materials, and recycling provides EU industries with essential supplies recovered from waste [27, p. 6]. Therefore, all the EU member countries classify coal combustion wastes (CCWs) as non-hazardous and interpret the EU regulations into their own domestic legislation. For example, the Netherlands recycles 100 per cent of its coal ash because landfill is not allowed in the country. In Germany, where around 10 million tonnes of coal ash are produced per year, around 97 per cent is re-used, with the rest stored only on a temporary basis [28]. However, the level of development of the circular economy varies greatly from one European country to the other depending on a country's level of natural resource endowment and its socio-economic context.

Unlike EU countries, there was a lively debate in the USA about recycling the CCW. The decision by the Environmental Protection Agency to revisit the potential classification of CCWs as a hazardous material in 2008 led to a steady downturn in total utilization through 2014. On 19 December2014, the Agency once again expressed its support for beneficial use activities.

It should be noted, that coal was the second-largest energy source for U.S. electricity generation in 2017 — about 30%. But coal consumption in power industry since 2007 has been decreasing each year. As a result, it has decreased by 36% over 10 years (from 1045.1 million tonnes in 2007 to 664.7 million tonnes in 2017).

Notwithstanding President Trump's decision to revive the American coal industry, according to IEA, electric coal consumption in power sector is expected to decline more than 10 percent, within the next five years. Instead, the consumption of all other sources of energy, especially gas, due to the decrease in prices for it, will increase significantly.

Moreover, in order to support the American coal industry, D. Trump announced 1 June 2017 that the United States would withdraw from the Paris climate accord, weakening efforts to combat global warming.

Consequently, focusing on the inexpedient development of thermal power generation, the US government ignores the consideration of other weighty solutions relating to the energy market, especially nuclear power regulation.

The USA is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity. For countries that use a large amount of nuclear energy, a spent fuel is a major problem because it has to be either recycled or disposed of. The USA has 99 nuclear power reactors in 30 states, but there are no nuclear fuel reprocessing plants are now operating, though three have been built. The first, a 300 t/yr plant at West Valley, New York, the second was a 300 t/yr plant built at Morris, Illinois, the third was a 1500 t/yrPurex plant at Barnwell, South Carolina. However, plants were shut down due to changes in government policieswhich ruled out all US civilian reprocessing as one facet of US non-proliferation policy.

In return, in May 2017 $150 million was allocated to restart licensing activities for siting interim storage at Yucca Mountain. Yucca Mountain in Nevada is the sole initial repository of high-level wastes. By 2020 the inventory of used fuel awaiting disposal is expected to be 88000 tonnes.

Therefore, in the United States, the possibility of reprocessing of used fuel is excluded. But it should be noted

that reprocessing used fuel to recover uranium (as RepU) and plutonium (Pu) avoids the wastage of a valuable resource.Both can be recycled as fresh fuel, saving up to 30% of the natural uranium otherwise required. Thus, this contributes to national energy security. A secondary reason is to reduce the volume of material to be disposed of as high-level waste to about one-fifth. In addition, the level of radioactivity in the waste from reprocessing is much smaller and after about 100 years falls much more rapidly than in used fuel itself [29].

Hence, in the United States, there is at present no federal mechanism dealing with the circular economy as a whole.The degree to which various circular economy initiatives are adopted very much depends on each State: California - probably the most advanced State in this regard - introduced a zero-waste objective into its legislation in 2002. Other States have launched no particular initiatives [20].

Despite US policy, some other states of the world (France, United Kingdom, Russia, Japan, India) chose to reprocess and recycle these materials (Table 2).

Table 2

WORLD COMMERCIAL REPROCESSING CAPACITY [29]

Type of fuel	Reprocessing facility	Capacity (tonnes per year)
LWR (light-water reactor) fuel	France, La Hague	1700
	UK, Sellafield (THORP)	600
	Russia, Ozersk (Mayak)	400
	Japan (Rokkasho)	800* (expected to start operation in 2021)
	Total LWR (approx.)	3500
Other nuclear fuels	UK, Sellafiels (Magnox)	1500
	India (PHWR, 4 plants)	330
	Japan, Tokai MOX	40
	Total other (approx)	1870
Total civil capacity		5370

Moreover, Japan is planning to start up a major (800 t/yr) plant at Rokkasho in 2021.The AEC fuel cycle subcommittee had noted that in each case reprocessing and recycle of used fuel is economically much better – by about 20% – than direct disposal. In May 2016 Japanese parliament passed a bill aimed at "taking measures necessary for the steady implementation of the reprocessing of used nuclear fuel".

It should be noted that in Japan, transition to the circular economy is considered as a way of compensating for the country's lack of natural resources and scarcity of space, because Japan has no indigenous uranium and buy it from Australia, Canada, Kazakhstan and elsewhere.It is based on the 3-Rs (reduce, reuse, recycle) and the desire to create a "Sound Material Cycle Society": that is a society in which the consumption of natural resources is preserved and the environmental impact reduced through the application of a 3R approach to wastes.

France, EU's largest producer of nuclear power, chose the closed fuel cycle at the very beginning of its nuclear program.In France, spent fuel from that country's 58 nuclear power plants is shipped to a recycling facility at Cap La Hague. As a result, France today generates 80 percent of its electricity needs with nuclear power, about 20% of it generated through recycling. Moreover, La Hague provides about 11000 jobs and about $600million for the local economy.

In the conditions of integration of the united power system of Ukraine into the pan-European energy grid ENTSO-E there are a number of economic, political and technological risks. In these conditions, the main thing is to harmonize the approaches to implementing the principles of the circular economy in the functioning of the electricity market.

Necessary legislative requirements that will stimulate the production of renewable energy and provide priority for development for such enterprises. The current situation in the field of energy regulation, when DTEK's thermal power plants receive subsidies, is unacceptable. The corruption component of such a decision demobilizes alternative energy producers and disrupts work carried out in this direction.

A reasonable approach to the calculation of electricity tariffs, taking into account the investment component, can become a leverage that will stimulate the development of the energy sector of Ukraine on the basis of the circular economy.

Conclusions. The results of the study proved that the circular economy comes already true in national energy strategies and concerns mainly reprocessing and recycle

of used fuel, such as coal combustion waste and nuclear fuels; yet the core aspects of the circular economy varies depending on a country's level of natural resource endowment and its socio-economic and politic context. Thus, despite the promising state of sustainability in the energy industry, there is clearly room for improvement for different countries and Ukraine in particular.

The scientific novelty of this study is the definition of potential economic benefits of circularity in the energy industry, which, unlike the existing ones, takes into account the subject-functional structure of the energy markets. It enables to consider its significance for each economic entities acting on the energy market of every hierarchical level.

The authors see potential need in research in the identification of factors which stimulate the development of the circular economy in the energy industry.

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