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Economic benefits for producers of biogas from cattle manure within energy co-operatives in Ukraine

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ABSTRACT

The paper deals with animal manure usage in order to produce biogas for energy generation in Ukraine. Although there are favorable conditions to develop the biogas sector based on animal manure, the share energy, which is produced from it, is extremely low (about 0.2% as of 2016). The paper analyzes energy potential of agricultural biomass in Ukraine, economic tools, aimed at stimulating electricity generation from biogas based on animal manure, the results of their impact on biogas plants deployment. Among a number of barriers, which slow down development of this sector in Ukraine, the main ones are the need for significant initial investments to construct profitable biogas plants and a large amount of raw materials for their uninterrupted operation. Given the fact that 48.2% of farm animals are concentrated in small-scale farms and households, which cannot individually implement biogas projects, it is proposed to combine their financial and raw material resources within energy co-operatives. Economic benefits, which may be gained by small-scale farms owners within energy co-operative through the sale of electricity, generated from biogas, by feed-in tariff are calculated. The results of research show that at the current level of feed-in tariff, the payback period of the biogas plant based on cattle manure, built within energy co-operative, is 4.6 years which is quite attractive for investors. It is discussed that in addition to economic benefits for small-scale farms owners, realization of the co-operative model in the bio-energy sector will create a number of ecological and social benefits both for local communities, and the state as a whole.

Key words:

Biogas;
Animal manure;
Energy co-operative;
Renewable energy;
Ukraine;

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1. Introduction

Nowadays the growing demand for renewable energy sources (RES) in energy production is observed, that actualizes the issue of increasing their share in the total energy mix of each country. Substitution of energy generation conventional technologies by renewable energy (RE) ones helps to solve many problems, related to the increase of countries' energy independence level [1, 2], the decrease of anthropogenic impact on the environment [3, 4], the creation of new jobs etc. [5, 6].

Ukraine urgently needs to solve a number of the aforementioned problems through RES potential development. Firstly, although Ukraine has reserves of all fossil fuels (oil, natural gas, uranium, coal), at present, they provide about 47–50% of the country's energy raw materials, the rest is imported [7]. Secondly, beginning from 1991 till today Ukraine leads the world in CO_2 emissions per GDP unit and is among the top-30 countries in the world, which are the largest polluters of CO_2 emissions as a result of the fossil fuel use [8, 9]. Thirdly, RE development is caused by the necessity to fulfill obligations, taken within the country's membership in the European Energy Community, where Ukraine has obligations to reach 11%-level of energy, generated by RES, in the country's final energy consumption till 2020 [10].

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It should be noted that RE share in the world energy mix as of late 2015 was 19.3%, 14.1% of which was accounted for biomass [11], i.e. this energy resource provides the biggest share of energy from RES in the world. In its turn, biogas production technology through anaerobic digestion is widely used among a number of biogas technologies. So, for instance, in the European Union in 2015 total production of biogas from sewage sludge gas amounted to 17%, from landfill gas – 9%, whereas biogas from anaerobic digestion (decentralised agricultural plants, centralised co-digestion plants, and municipal solid waste methanisation plants) made up 74% [12]. Dynamic development of this sector is caused firstly, by the flexibility of biogas as an energy product, particularly because of the possibility of production on its basis both thermal energy and electricity, and fuel for internal combustion engines. Secondly, as regards animal manure, it belongs to substrates, which are most reasonable to be used for biogas production (as a separate substrate, or mainly in combination with other substrates), since they are formed as secondary waste and have to be utilized in an ecologically safe way [13]. Another benefit of biogas technologies is the high coefficient of the installed capacity use by biogas plants and absence of energy generation amounts dependence on climate conditions. It beneficially distinguishes biogas plants from other RE generating capacities, particularly solar and wind power plants.

Although biogas production based on animal manure is dynamically growing in some countries of the world (China, the USA, India, Canada, UN-28 countries) [14], in Ukraine, where agriculture is a leading sector in the economy (it ranks the largest share in the structure of GDP among all sectors –17% of GDP in 2017) [15, 16], the bioenergy sector is being developed extremely slowly. As of the end of 2016, electricity share, generated from biogas from animal manure, in the country's final energy consumption was about 0.2% [17]. It should be noted that such tendencies in the development of the domestic biogas sector are observed despite the functioning of economic mechanisms aimed at encouraging the electricity generation from RES [18]. The last fact proves that there are many barriers in successful development of Ukrainian biogas sector, which cannot be compensated by high feed-in tariffs, tax and customs privileges etc.

The most significant obstacles, which slow down development of the domestic biogas sector based on animals manure and byproducts include the need for substantial initial investment to construct profitable biogas plants and a large volume of animal manure for their uninterrupted operation [19]. To our minds, one of the variants to eliminate these barriers is to improve the current legislation with regard to energy cooperatives formation. It will create favorable organization and economic conditions to unite financial and raw material resources for joint implementation of biogas projects.

The main aim of this research is to assess economic benefits for owners of small-scale farms, which produce biogas from animal manure within energy cooperative in Ukraine.

2. Potential of biogas production from animal manure in Ukraine

The agricultural sector of Ukraine is a leading field of the national economy. A large area 603628 km^2, 70.9% of which are agricultural lands, fertile soil and good climate conditions provide favorable preconditions for animal husbandry and crop production development. The production of a large amount of agricultural waste provides good opportunities to the domestic bioenergy sector development.

The theoretical potential of agricultural waste in Ukraine is demonstrated in Table 1 [20].

However, among various types of agricultural waste the utilization of animal manure through the biogas production is of particular interest, since in addition to energy benefits, it has certain ecological value.

A peculiarity of most Ukrainian agricultural enterprises, private farms and households is to accumulate and to keep manure or droppings in the open-air lagoons [13]. Then they are put on fields as an organic fertilizer. Accumulation of manure and droppings in this way causes land and water pollution. Besides, in case of fertilization above the norm, soil is over-enriched with nutrients [13]. It leads to reduction of soils fertility and decreasing lands, which may be used in agriculture. Moreover, manure and droppings is a source of ammonia, methane, nitrous oxide and other gases emissions to the

Table 1: The energy potential of agricultural waste in Ukraine

Type of agricultural waste	Theoretical potential per year, PJ
Straw of crops	1281.16
Waste of corn production for grain	1683.09
Waste from sunflower production	879.23
Biogas from manure (or droppings)	59.2

atmosphere, which contribute to global warming and climate change of the planet [13]. Thus, anaerobic digestion of manure and droppings enables not only to gain some economic benefits by means of decentralized production of electricity and thermal energy, but also to prevent some ecological problems.

It should be noted that in 2016, the agricultural sector accounted for 10.4% of the GDP of Ukraine. In 2016 Ukraine took the third place in Europe and was among the top ten exporters of agricultural goods to the European Union countries by this indicator [16].

It is worth noting that the animal husbandry share in the structure of Ukraine's agricultural production was about 50% as of the end of 2016 [16]. One of the absolute indicators of animal husbandry development is the current number of farm animals, the quantity of which in Ukraine as of the end of 2016 is shown in Table 2 [16].

A peculiarity of the Ukrainian animal husbandry is the fact that almost half of the above number of farm animals is concentrated in small-scale farms and households (Figure. 1).

Today a lack of financial and raw material resources for individual implementation of biogas projects by such economic entities makes impossible to use the existing animal manure for energy production. The great driver for this direction development could be state support tools (feed-in tariff, tax and customs privileges); however, although they have been introduced, they do not take into account peculiarities of energy production from bioenergy resources, therefore their efficiency in this field leaves much to be desired.

Table 2: Number of farm animals as of the end of 2016

Type of farm animals	Million head per year
Cattle	3.68
Pigs	6.67
Horses	0.31
Poultry	201.67
Sheep and goats	1.31

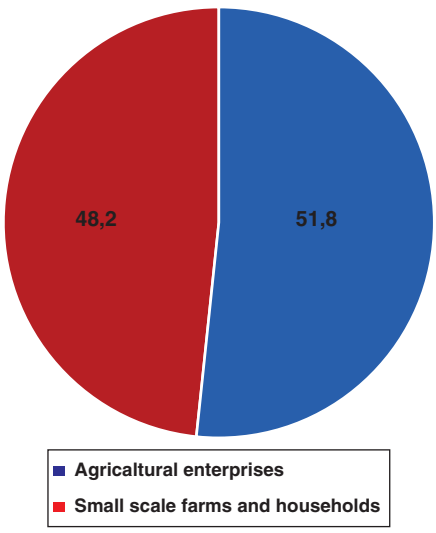

Figure 1: Structure of the farm animals placement in Ukraine [16]

3. Economic tools to stimulate electricity generation from biogas based on animal manure and effect of their introduction

Since 2009 a number of state strategy programs in the RE field have been introduced, particularly Energy Strategy of Ukraine till 2030 and National Action Plan for Renewable Energy for the period until 2020 [10, 21], where RE development is defined as a key vector to reform domestic energy sector. In order to achieve strategic goals regarding RE deployment, the country's government formed RE regulatory basis and introduced motivating mechanisms, oriented to promote electricity generation from RES. It should be mentioned that mechanisms to stimulate RE development in Ukraine are unique for all RE technologies. Let us consider main ones from the standpoint of electricity generation from biogas based on animal manure and byproducts:

Feed-in tariff. According to the Law of Ukraine "On Electric Power Industry" [22], feed-in tariff is a special tariff, by which electricity, generated from RES, including from biomass, is purchased.

According to [22] biomass is non-fossil biologically renewable organic substance, which is able to biological decompose. It includes waste of forestry and agriculture (crops farming and animal husbandry), fish farming, the industrial and domestic waste, which is able to biological decompose.

Minimum feed-in tariff rate is fixed and is calculated according to the algorithm, given in [22]. Minimum feed-in tariff rate is reviewed by National Commission for State Regulation of Energy and Public Utilities of Ukraine (NCSREPU) every month and is converted in EUR by an official currency rate of National Bank of Ukraine with the purpose to protect economic entities, generating electricity from RES, from possible inflation.

The Law of Ukraine [22] provides the fixed allowance to feed-in tariff for the use of domestically made equipment in RE power plants construction, including biogas plants based on animal manure. While using equipment of the Ukrainian production at the level of

30% and 50% for power plants, put into operation since July, 1, 2015 till December 21, 2024, the rate of additional allowance to feed-in tariff is 5% and 10% relatively.

Terms of economic stimulation scheme with the help of feed-in tariff is established from 2009 to 2030. State guarantees to purchase the whole amount of electricity during the above period.

Tax and customs privileges. According to p. 197.16 and p. 213.2.8 of Tax Code of Ukraine [23] and pp. 14 and 16 Article 282 of Customs Code of Ukraine [24] there are following privileges:

- exemption from paying value added tax for equipment, supplements, used to o generate energy from RES, including from biogas based on animal manure.
- exemption from paying customs duties for import of material, raw, equipment and supplements, used in production of alternative fuels or energy generation from RES, including from biogas based on animal manure.

One may use the above tax and customs privileges only if identical goods with analogical qualitative features are not produced in Ukraine.

However, although, there are many motivating mechanisms for RE development, the RES share in total electricity mix of Ukraine is low, and as of the end of 2016 it was only 1.3% (Figure. 2).

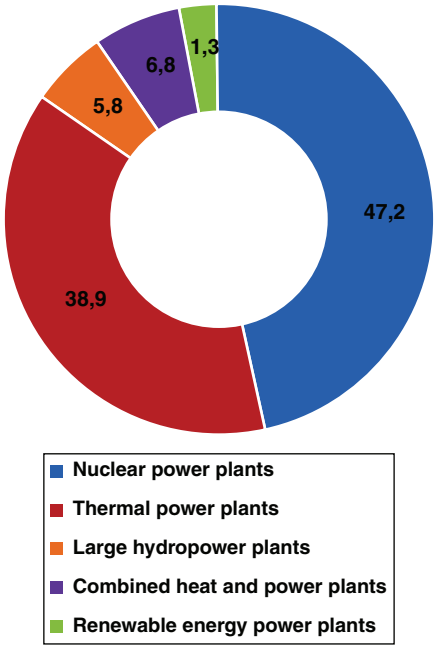

Figure 2: Total electricity mix in Ukraine as of the end of 2016 [17]

In its turn, there was the least share of the bioenergy sector (bioenergy power plants based on landfill gas, agricultural biomass, solid biomass) in the structure of electricity, generated from RES, among all RE technologies and was 6.6% at the end of 2016 (fig. 3). And finally, the electricity share, generated from agricultural biogas, as of the end of 2016 was 1.6% (animal and crop biomass), and, relatively, took the least ratio in the structure of electricity generation from RES (Figure. 3).

Based on the above data, we can conclude that current economic mechanisms lead to certain RE development, but unfortunately they were not able to provide their large-scale growth. Uneven development of various RE technologies, of which, biomass took the lowest position, perhaps, due to the fact that the above support mechanisms do not to take into account peculiarities of electricity generation, based on various RES.

As for biogas plants based on animal manure, today there are only 6 (Pig farm of the enterprise *Zaporizhstal,* Zaporizhya, number of farm animals – 12000, raw type – pigs' manure; Pig farm of corporation *Agro-Oven,* Olenivka, Dnipropetrovsk region, number of farm animals – 15000, raw type – pigs' manure; Agricultural company *Elita,* Terezyne, Kyiv region, number of farm animals – 1000, raw type – manure of cattle and pigs; Cattle Farm *UMK,* V.Krupil, Kyiv region, number of

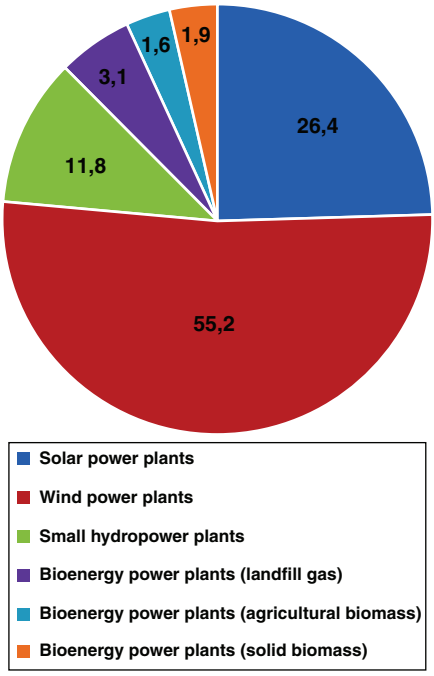

Figure 3: Total mix of electricity from RES in Ukraine as of the end of 2016 [17]

farm animals – 6000, raw type – cattle manure; Poultry farm *Oril – Leader*, Yelizavetovka, Dnipropetrovsk region, number of poultry – 42154326 per year, raw type - poultry's droppings and silage; Pig complex *Danosha*, Kopanky, Ivano-Frankivsk region, number of farm animals – 5800, raw type – pigs' manure) and also some projects of biogas plants are being constructed now [13].

The above data prove that all active biogas plants run on animal manure of large agricultural enterprises, which indicates to the fact that small-scale farms and households potential is not developed.

4. Barriers for successful implementation of biogas projects based on animal manure

The main reason, which caused great lagging of biogas sector based on animal manure in particular in comparison with other RE technologies, was the absence of a feed-in tariff for bioenergy power plants during the long run. If feed-in tariff for other RE technologies was introduced in 2009, for bioenergy power plants it has been implemented only since April, 1, 2013. However, in addition to this fact, it is possible to identify a number of other barriers that hinder the large-scale deployment of biogas power plants based on animal manure. Let us consider them in more detail:

- Need for significant initial investment to build biogas plants [19]. In spite of the technological progress, which has resulted in a gradual reduction of cost for energy generation from biogas, nowadays construction of biogas plants based on animal manure requires great financial resources. The absence of state programs, which allow to involve credits resources by farms on favorable terms and at preferential interest rate, aggravates this problem.
- Lack of large-scale farms, which are capable of producing necessary volumes of animal manure for profitable biogas plants exploitation. As mentioned above most farm animals in Ukraine are concentrated in the individual households and small agricultural farms [16], that is why construction of the profitable biogas plants is possible, provided that they cooperate;
- Absence of the stable legislative basis in the RE field in general and bioenergy in particular. Since economic mechanisms to stimulate RE development have been introduced, the parliament has made a number of changes in laws, which control activity of the economic entities in this field, particularly regarding feed-in tariff coefficient changing, requirements to the local content in the RE projects realization, terms regarding RE power plants connecting to electricity network, lands allocation for RE plants construction etc. [22]. Such actions undermine investors' confidence and may cause investors' activity closing in Ukraine.
- State's subsidization of prices for natural gas, electricity and thermal energy for citizens makes the transition to use biogas unprofitable within the decentralized energy and heat supply. Thus, 3.7 billion US dollars are included to the budget of Ukraine for 2018 for specific subsidies to pay for utilities [25].
- Absence of strict ecological requirements, which would encourage effective utilization of manure through its anaerobic digestion at biogas plants in order to reduce environmental risks, caused by them [13].
- Absence of feed-in tariff to produce thermal energy and fuel from biogas for internal combustion engines;
- Absence of the state program promoting organic fertilizers use to improve soil structure and to increase its fertility.

Thus, summing up the above, we can conclude that it is necessary to improve regulatory base for more dynamic development of the agricultural biogas sector. It will allow to create better frame conditions for biogas projects implementation.

5. Energy co-operatives as a driver for development domestic biogas sector based on animal manure

Imperfection of biogas sector state regulation requires looking for new decisions, which are able to increase investment activity in this field. Taking into account the fact that today, main barriers in successful development of biogas sector based on animal manure are high capital cost for biogas plants construction and need for large amounts of animal manure for their uninterrupted operation, one of the variants to solve the above problems is self-organization of small-scale farms into energy co-operatives.

In general formation of the co-operative movement in the Ukrainian bioenergy sector may lead to:

– the mastering of farms' bioenergy resources potential and their rapid involvement into the total energy mix of the country;

- the formation of the decentralized energy supply, which provides construction of RE plants with small capacity and distribution networks in close proximity to consumers, what is more effective from the viewpoint of cost reduction for energy transportation;
- the increase of competitiveness level in the energy field, since the Ukrainian energy market peculiarity is the fact that enterprises, which generate energy and provide its supply service, take a monopoly position [26]. As a result, monopoly power abuse is often a reason to fix an economically unjustified tariff for electricity and thermal energy, provision of low-quality service regarding electricity and thermal supply;
- the revival of Ukrainian villages, at present most of them suffer from social and economic decline, resulting from the lack of jobs and rapid reduction of the rural population, caused by its migration to cities in order to find better quality of life. That is why the, co-operation of the population in the rural area with the purpose of joint bioenergy projects realization may have a positive impact on the unemployment problem solving in the rural area, on localities infrastructure development, quality and welfare of rural population on the whole.

Although Ukraine has huge potential for co-operative models in the bioenergy sectors, the absence of the holistic legislative base to create energy co-operatives does not allow to develop this sector with desired rates.

Nowadays activity of co-operatives in Ukraine is regulated by a number of laws, particularly "On Co-operation" [27], "On Agricultural Co-operation" [28], "On Consumer Co-operation" [29], norms of which essentially limit energy co-operatives activity.

One of the disadvantages of the above laws is the absence of the concept "energy co-operative", and consequently the absence of permission or prohibition for its creation. That is why, today conditions of energy co-operatives formation are regulated by the general rules, related to consumer, production or service co-operatives:

- production co-operative provides an ability to unite only individuals with purpose to gain profit;
- service co-operative enables to unite either individuals or legal entities, and its goal is not to gain profit;
- consumer co-operative provides an ability to unite either individuals or legal entities, and its goal is not to gain profit.

Thus, absence of the concept "energy co-operative" in current legislation makes it impossible to get financial support by energy associations within state and local support programs on energy saving, energy efficiency and alternative energy development. Besides, there are some difficulties to select the co-operative type, because the above legislatively approved co-operative types do not completely show abilities to operate in the field of energy production and supply.

A barrier in the large scale-farms' energy co-operatives deployment is a requirement regarding the obligatory licensing of the activity energy production from bioenergy resources, even if it is performed entirely to satisfy energy co-operatives members' needs. Today energy production from bioenergy resources is subject to licensing, if total installed capacity of bioenergy plant exceeds 5 MW [30].

Another norm of the current legislation in the energy co-operation field, which does not encourage the intensive deployment of bioenergy plants, is taxation of activity on the sale of electricity and thermal energy selling, including those cases, when it is produced for energy co-operative members' consumption [31]

An essential disadvantage of the current legislation is the regulation of tariff for electricity and thermal energy production and supply even if such activity is performed to fulfill energy co-operative members' needs. For instance, the tariff for the supply of heat by the energy co-operative to its members is established by local authorities [31].

Thus, nowadays, the full-fledged activity of energy co-operatives in Ukraine is limited by the imperfection of legislation in this field. In order to realize the co-operative model successfully in the bioenergy sector in Ukraine, it is necessary to create an effective legal and regulatory framework to control decentralized production and consumption of energy from bioenergy resources, to form regular state and regional programs, which will combine informing of local communities regarding economic, social and ecological benefits from energy co-operatives formation with methodic and financial support of initiative groups.

In order to prove that joint implementation of biogas projects can bring significant economic benefits for investors, we will carry out approbation on the example of the union of small-scale farms in the energy cooperative to construct and operate a biogas plant based on cattle manure in one of the regions of Ukraine.

6. Methodology

In order to calculate economic benefits from construction and exploitation of the biogas plant based on cattle manure within the energy co-operative, we will calculate cost of electricity generation and assess payback period of the investment project if electricity excess is sold (amount, which exceeds needs in electricity of the energy cooperative) by feed-in tariff according to the current legislation.

The electricity cost will be calculated by the Levelised Cost of Energy (LCOE) method, which is widely used by International Energy Agency and International Renewable Energy Agency to assess cost for electricity generation from renewable and non-renewable energy resources [32, 33]. The LCOE presents fixed electricity tariff at which total discounted revenue from electricity selling to final consumers is equal to the total discounted cost during the lifetime of the power plant [34]. In other words, it is a minimal price, at which electricity, generated during the lifetime of the biogas plant, has to be realized to achieve its break-even point (Net Present Value, NPV = 0). If the price for electricity is higher than LCOE, it will provide larger profitability for invested capital (NPV > 0), than discount rate, which was taken for calculation. At the same time, lower price will not let the project to be paid back with the given discount rate (NPV < 0).

The following constituents will be considered to calculate cost of electricity from biogas based on animal manure within energy co-operative, created by farms: capital and operating cost, amount of the generated electricity, decommissioning cost of biogas plant and discount rate. Fuel component cost in the structure of operating cost for electricity generation from biogas will be taken as zero, because animal manure can be considered as free for farms owner.

Taking into account the above constituents, above condition of equity of total discounted incomes and cost can be shown in the following way:

$$\sum_{t=0}^{n}(E_t \cdot LCOE)\cdot(1+r)^{-t} = \sum_{t=0}^{n}(I_t + O_t + D_t)\cdot(1+r),^{-t} \quad (1)$$

where *LCOE* is fixed cost of electricity generation during the whole lifecycle of the biogas plant, EUR/MWh; D_t – decommissioning cost of biogas plant in *t*-year, EUR/MWh; E_t – amount of generated electricity in *t*-year, MWh; *It* – investment cost in *t*-year, Euro MWh; Q_t – operating cost in *t*-year, Euro MWh; *n* – duration of the biogas plant's lifecycle, years; *r* – discount rate; *t* – year of the project implementation.

That is why, *LCOEs* can be calculated by the formula:

$$LCOE = \frac{\sum_{t=0}^{n}((I_t + Q_t + D_t)\ \cdot\ (1+r)^{-t})}{\sum_{t=0}^{n}(E_t \cdot (1+r)^{-t})}, \quad (2)$$

The feed-in tariff rate to purchase electricity, generated from biogas based on animal manure in Ukraine, will be calculated according to algorithm, given in the Law of Ukraine "On electric Power Industry". According to [22] minimum feed-in tariff is calculated by the formula:

$$FT_{\min} = RP \cdot k, \quad (3)$$

where FT_{min} – minimum feed-in tariff for electricity, generated from biogas based on animal manure; *RP* – retail price for electricity for the second-class-voltage consumers as of January 2009 (0.5846 UAH/kWh); *k* – feed-in tariff coefficient according to [22].

Dynamics of feed-in tariff coefficients changing forbiogas plants, based on animal manure,is demonstrated in Table 3 [22].

Every month the minimum feed-in tariff is reviewed by NCSREPU through their recalculation according to EUR exchange rate as of 01.01.2009 by the following algorithms:

$$\text{If}\frac{\text{UAN}}{\text{UAN}\ \ 01.01.2019} \geq 1,\ \ FT = FT\ \ 01.01.2019 \times \frac{(\text{UAN}}{\text{UAN}\ \ 01.01.2019),} \quad (4)$$

$$\text{If}\frac{\text{UAN}}{\text{UAN}\ \ 01.01.2019} \leq 1,\ \ FT = FT\ \ 01.01.2019, \quad (5)$$

where *FT* – feed-in tariff as for date revision, UAH/kWh; *FT* 01.01.2009 – feed-in tariff as of January, 1, 2009, UAH/kWh; UAH – official UAH exchange rate according to EUR exchange rate, set by National Bank of Ukraine for date of feed-in tariff revision, UAH; *UAH*

Table 3: Dynamics of feed-in tariff coefficients changing for biogas plants, which use animal manure for electricity generation in Ukraine during 2017–2030

Feed-in tariff coefficients for biogas plants, which use animal manure for electricity generation, put into operation:		
from 01.01.2017 till 31.12.2019	from 01.01.2020 till 31.12.2024	from 01.01.2025 31.12.2029
2.30	2.07	1.84

01.01.2009 – official UAH exchange rate according to EUR exchange rate, set by National Bank of Ukraine as of January, 1, 2009, UAH (10.85546 UAH for 1 EUR).

The payback period of the biogas plant, built within the energy co-operative, will be calculated by the formula:

$$pp = \sum_{t=1}^{n} CF_t \geq IC_{0,} \quad (6)$$

where *PP* – payback period of the investment project; IC_0 – initial investment during zero period (year), EUR; CF_t – net cash flow in *t-year*, EUR; *n* – duration of the project lifecycle, years; *t – year* of the project implementation.

7. Result and discussion

Formation of the energy co-operatives requires a meaningful approach to study technical and economic peculiarities regarding bioenergy projects implementation in Ukraine. It should be noted that nowadays it is economically reasonable to build biogas plants in Ukraine, total installed capacity of which is 500 kW and more [19]. That is why, it is rationally to create energy co-operative, which will be able to provide necessary amount of raw material for a profitable biogas plant. In order to provide work of the biogas plant with such capacity, 100 tons of manure per day, provided by 2000 head of cattle, are required. One of variants to produce such amount of manure for biogas plant uninterrupted work is to unite several farms.

Let us consider an opportunity to create energy co-operative for joint construction and exploitation of the biogas plant, based on cattle manure as substrate, through example of the agricultural co-operatives (Kolyadynets, Beyevo, Voropayi, Moskovske) of Sumy district, Lypovodolynsky region. The above-mentioned agricultural cooperatives possess 740, 660, 580 and 620 head of cattle respectively, which together makes up 2600 head of cattle.

Let us consider real technical and economic indicators of the biogas plant and assumptions, on the basis of which cost of electricity generation from biogas within energy co-operative will be calculated, in more detail:

1. General data and technical features of biogas plant:
   - head of cattle in the proposed energy co-operative – 2600;
   - type of the substrate – cattle manure;
   - amount of substrate according to the present head of cattle per day – 130 t [35];
   - average biogas production according to the chosen substrate per day – 34 m^3/t [35]. Thus, the annual amount of biogas according to cattle manure volume in the proposed energy co-operative will be 1.59 mln m^3;
   - the average amount of electricity from 1 m^3 of biogas is 1.9 kWh [36]. That is why the predicted annual amount of electricity generation (gross production) will be 3.02 GWh;
   - the annual amount of electricity, which is required for technological needs of biogas plant, is at the level of 5% from gross production [19] – 151.2 MWh;
   - the amount of additionally consumed electricity by the above agricultural co-operatives in 2016 was 441.7 MWh.

Thus, the predicted annual electricity excess, which will be sold by feed-in tariff, having covered energy co-operative's own needs in electricity, will be 2.43 GWh.

   - total installed capacity of the biogas plant, taking into account the above features, will be 643 kW.
   - duration of the biogas plant construction – 1 year.
   - duration of the biogas plant lifecycle – 20 years [19].

2. Predicted investment cost. Nowadays, an average cost of 1 kW of the biogas plant installed capacity in Ukraine is 2000 EUR [19]. Distribution of investment cost by items was fulfilled on the basis of implemented biogas projects in Ukraine in 2012–2016 and recommendations of international organizations in the energy sector [19, 34], and may be demonstrated in the following way:
   - technical and economic justification of the biogas plant project – 68500 EUR;
   - construction and installation works – 364000 EUR;
   - cost for equipment and supplements – 722000 EUR;
   - cost to connect biogas plant to electric network – 80000 EUR;
   - other unplanned cost – 51500 EUR.

   Thus, total investment cost will be – 1.29 mln EUR.

3. Operation and maintenance cost:
   - cost for salary – 6000 EUR/year;
   - cost of substrate (manure of cattle) is taken as zero;
   - cost for technical service – 20600 EUR/year;
   - other cost (land lease, insurance, transport cost etc.) – 30700 EUR/year;

Thus, total and maintenance cost will be – 57300 EUR/year.

4. Decommission cost of biogas plant – 25720 EUR (at 2% of investment cost).

Discount rate in EUR to implement projects in the energy field in Ukraine in 2016 was 12% [17], this index will be used for LCOE calculation. It should be mentioned that discount rate in Ukraine is high enough in comparison with other countries. It is related to high risks to do business in Ukraine, caused by the Russian military intervention and armed conflict in the east of the country.

Based on the above data and assumptions, calculated LCOE in 1 MWh of electricity by the formula (2) is 37.5 EUR/MWh.

In order to calculate the main economic effect, we found the minimum feed-in tariff for of 1 kWh of electricity from biogas within the proposed energy co-operative. The calculated minimum feed-in tariff by formula (3) and taking into account feed-in tariff coefficient for biogas power plants, put into operation since 01.01.2017 till 31.12.2019 (see Table 3), is 0.04 EUR/kWh.

As mentioned above this feed-in tariff value is reviewed through its calculation according to EUR exchange rate as of 01.01.2009. Having compered official exchange rates of UAH according to EUR exchange rate, fixed by National Bank of Ukraine as of 05.04.2018 (32.47 UAH/EUR) and 01.01.2009 (10.85 UAH/EUR) according to algorithms (4, 5), the calculated feed-in tariff for 1 kWh of electricity, generated from biogas as of 05.04.18 was 0.12 EUR/kWh. Thus, feed-in tariff by which electricity, generated from biogas based on cattle manure within proposed energy co-operative, will be sold, is more than three times higher than cost for electricity generation, calculated by LCOE with a 12% discount rate.

Taking into account the fact that the annual predicted amount of electricity, which will be sold by the proposed energy co-operative after covering own energy needs is 2.43 GWh, annual revenue from electricity sale by feed-in tariff will be 300145 EUR.

Based on the above data and formula (6), the calculated payback period of this investment project is 4.6 years which is quite attractive for investors, because it can guarantee fast return of initial investment.

In addition to the profit from sale of electricity by feed-in tariff, members of the energy co-operative may get good benefits from thermal energy consumption, which is produced without additional burning of biogas, when electric generator is cooled. Thermal energy may be used for agriculture premises heating, greenhouses, for seeds drying and district heating in the village.

It should be mentioned that one of the advantages of biogas plants is production of organic fertilizers during the biomass anaerobic digestion process at the biogas plant. Besides financial effect from funds saving to purchase mineral fertilizers, using of such organic fertilizers for farms needs will allow to get positive agrotechnical effect, caused by their advantages, namely: maximum storage and accumulation of nitrogen, high level of organic substance humification, absence of weed seeds and pathogenic microflora, resistance to the soil washout etc. Thus, their use will let not only to improve physical and mechanical properties of the soil, to increase yield of crops, and in future it may help to produce competitive environmentally friendly products both at the domestic markets and markets of other countries.

It should be noted that joint exploitation of the biogas plant within the energy co-operative, besides above benefits, can have positive impact on environment. The anaerobic digestion of manure will let partially to solve problems concerning manure, namely to reduce risk to pollute soils and water, to decrease methane and other greenhouse gases emissions to the atmosphere. That is why rational use of the animal manure is an essential argument for biogas technologies development with purpose to decrease processes of the global warming and climate changes.

In addition to the economic and ecological benefits, the implementation of the biogas projects within energy co-operatives can have a certain social effect. Construction and exploitation of biogas plants may assist creating new jobs and partially solve the employment problem in the rural areas. Payment of taxes to the rural budgets may help to develop settlements infrastructure, which will have positive impact on quality and welfare of the rural population.

8. Conclusion

Today the potential of agriculture in Ukraine is of great interest to provide not only supply of food and food security, but also country's energy independence. One of the key directions in the bioenergy sector development is the use of animal manure for biogas production. Perspectives to develop this technology are caused by the wide net of animal complexes in Ukraine which annually produce large amounts of manure. However, today, absence of the

effective legislation to regulate decentralized production and consumption of electricity from biogas based on animal manure slow down growth of this direction.

The conducted analysis confirms that one of the variants to improve the situation in the Ukrainian bioenergy sector is development of regulatory framework in part of energy co-operatives formation with purpose to unite financial and raw material resources of small-scale farms for biogas projects joint implementation.

The results of research show that at the current level of feed-in tariff, the payback period of biogas plant, which generates electricity based on the cattle manure, and built within energy co-operative, is 4.6 years. It makes economic sense and guarantees rapid return of initial investment. Besides, when payback period is finished, members of the energy co-operative will be able to continue to sell electricity from biogas by feed-in tariff till 2030 (the term of the end of the state support scheme of RE development by means of feed-in tariff). It means that farms owners will be able to receive significant profits after the end of the investment project payback period.

In addition to economic benefits for farms owners, the realization of co-operative model in the bioenergy sector can bring substantial social and ecological benefits both territorial communities and state on the whole.

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