ENERGY ASPECT OF VERTICAL INTEGRATION IN AGRICULTURE

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Summary. The paper investigates the state of energy aspects of agricultural integrated companies. The study proved that the integration in the agricultural and industrial complex should be viewed more broadly including bioenergy production. The scheme of relationships within vertical integration has been developed. The comparative efficiency of vertically integrated and non-integrated companies has been examined. Farms and agro-food processing facility strive to reduce energy dependence. On the basis of researches, a new scientific definition has been suggested: an agro-energy company or the agro-energy vertical. For the agro-energy company, the ways of vertical and horizontal integration building have been considered. The authors' vision of the feasibility of alternative fuel production has been presented. Efficiency of biogas production and its utilization (including by-product) has been calculated. It has been proved that the use of by-products increases the profitability of biofuel production.

1. INTRODUCTION

In modern economic conditions, only companies with full production cycle can achieve success. A number of scientists emphasize that such way of production from raw materials to deep processing provides the highest level of their profitability, financial sustainability, a competitive advantage over other participants of the agricultural market. This may be applied to the production of renewable energy resources [see 25; 26; 35; 41].

The problems of the vertically integrated business structures and their functioning were investigated by a number of researchers. There are three possible ways for agricultural commodity producers to transfer their production from farm to processors: spot market, vertical integration, and agricultural contracts [30]. Vertical integration is widely accepted worldwide [3] but is less common in agriculture [20]. That is why agricultural producers do not always get the desired profitability.

The production of renewable energy resources in vertically integrated formations has been investigated by a number of researchers too [6; 11; 19; 27; 36; 37].

However, the changing economic conditions require additional research. So, the study of the functioning of vertically integrated structures in the agro-food sector is relevant and timely.

The purpose of this paper is to identify modern trends in the functioning of vertically integrated structures in the agricultural sector of the economy, especially in bioenergy production.

2. METHODOLOGY

The subjects of research were processes of vertical integration in biofuel and biogas production (agriculture and agro-food industry) in the counties which are the biggest producers and in Ukraine.

The basis for the information for the paper was gathered via a number of sources. Some projects operating have ceased. When possible, the information presented was derived from company sources. Only a few countries have precise figures for their annual biofuel and biogas production, including agriculture and agro food industry. So, the data for annual biofuel and biogas production are obtained from different sources.

Gathering information on the modern status in Ukraine remains a challenge, as there is no full official statistical information concerning biogas and biofuel production. The method used in this paper is the literature review with exploratory character and a quantitative research.

3. FEATURES OF VERTICALLY INTEGRATED COMPANIES

Vertically integrated companies of the agro-industrial complex (AIC) can be divided into some spheres:

1st sphere is manufacturing of the means of production for agriculture, food and processing industry (tractors, agricultural machines, equipment, etc.);

2nd sphere is agriculture (crop growing, livestock, poultry farming, fisheries, and forestry);

3rd sphere is transport and storage of agricultural raw materials and their processing, as well as sale. It includes the food industry, storage, and transportation, wholesale and retail trade.

Some researchers suggest adding some more spheres to the abovementioned ones. So, in addition to these, Andriychuk suggests adding 4th sphere – the market infrastructure (wholesale markets, auctions, trade network of agricultural producers and processing companies) and 5th sphere – production infrastructure [60].

In our opinion, it is advisable to outline 6th sphere – biofuel (solid, liquid and gaseous) production.

The integration processes are a part of the economic system. The forms of integration processes, the mechanism of their manifestation are carried out at micro- and macro level [5]. At macro level, the integration processes are formed on the basis of specialization and cooperation, and are characterized by close cooperation divisions. At macro level, this is an integration of business into a united integrated economic system. The organizational form of the above is a corporation.

Integration should be considered both at macro and micro levels.

The concentration of production and capital are associated with the growth of a company through its own capabilities. They are defined as internal resources (directing the profit share to the development of production) and external sources of financing (bank loans and emission of securities).

Centralization of production and capital is a growth of firms at the expense of joining industries through mergers. If the combining of enterprise passes equitably, it is then merged. And when one company buys another one, there is absorption. So, the possible consequences are diversification of production and penetration of capital in different industries and fields of activity.

The structure of a vertically integrated company contains several levels: the first level is the supply of raw materials; the second level is the processing and manufacturing of commodity for the final consumption; the third level is sales of finished products (*Figure 1*).

The production function of a vertically-integrated business is the following:

$$VIS = f(S_1, S_2, S_3, ..., S_n), \quad (1)$$

where *VIS* is the vertically integrated structure; *S* is the subsystem which is a part of a vertically integrated company; *n* is the number of subsystems involved in the production chain.

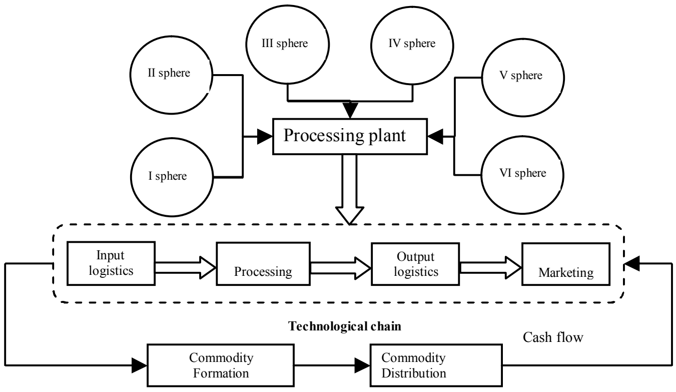

Fig. 1. The scheme of relationships within a vertically integrated association

Modern economic science pays special attention to the development of vertically integrated companies, since such structures are able to meet consumers' growing needs in food supplies.

The results of our studies on the effectiveness of vertical integration are displayed in *Table 1*. This example contains the following conditions: the costs of each stage (regardless of size) are equal to 1 (100%), the level of profitability – 0.3 (30%). This approach simplifies perception.

Table 1.
Comparative efficiency in vertically-integrated and non-integrated enterprises

Technological production chains	Costs				profitability
	Production	transportation	recycling products	sale	
Vertically-integrated enterprise	1	1	1	1	0.3
Total cumulative effect					**4.3**
Non-integrated companies					
- agriculture commodity producer (organic raw materials)	1				0.3
- trader or another mediator		1			0.3
- processing plant			1		0.3
- sales				1	0.3
Total cumulative effect	**1**	**1**	**1**	**1**	**5.2**

The above mentioned approach is primarily socially oriented and includes the calculation of price of agricultural commodity with 30 % profitability. At the same time, the participants of the non-integrated technological chain increase the price of production at every stage by up to 30 % in order to maximize their own business benefits, establishing an adequate level of profitability (based on the above example).

The cost of product, which is sold to the end consumer by vertically-integrated enterprises, should be cheaper compared with non-integrated production. The reason is as follows: each entity of non-integrated production lays its own profitability, but a vertically-integrated company forms profitability at the end of the value-added chain. The profitability of each stage of production is equal to zero. Sometimes, non-integrated companies use agents, for example, grain traders. They also strive to maximize their own revenues. At the final stage, some structures, such as wholesale and retail trade companies, appear. They also increase the final cost of product. So, the final price of goods to the consumer could rise (due to more than double increase of the original profitability).

The tax burden (tariff and non-tariff regulation) is not included in the proposed methods. It increases effectiveness of vertically-integrated production. They will take precedence over other operators of the products market. The vertically integrated production will have an impact both on the volume of sales and profitability.

Nowadays, agriculture is transforming from the consumer to the producer of energy resources. So, a vertically-integrated strategy may be used in the biorefinery branch.

4. VERTICAL INTEGRATION IN BIOFUEL PRODUCTION

Biofuel production may be organized in vertically-integrated companies. They can produce solid, liquid, and gaseous biofuels. So, energy vertical is being formed. Vertical integration is a well-known strategy of how to improve the security of supply of raw materials (downstream integration), as well as to strengthen its position in the market of final product (upstream integration).

The biofuel (bioethanol and biodiesel) value chain can be divided into three groups: upstream (feedstock), midstream (manufacturing segment), and downstream (blending, distribution and retailing of the final product) [14].

In modern economic terms, biofuel industry integrates different processes in the supply chain such as crop growing, transportation, biofuel production, refinery etc. In biofuel production cost the feedstock share constitutes up to 70-80%. In the case of upstream integration, biofuel producers have access to companies which own feedstock. It may be a farm, food processing facility, distillery, etc. So, they can get better control over the input costs of feedstock and can reduce their dependence on the market for sourcing feedstock. The backward integration has both attractive benefits and potential disadvantages. The backward integrated supply chain will reduce the cost of feedstock. But it lowers profitability of farming activity. It may force crop growers to switch to other more economically attractive crops. However, the downstream integrated business model can provide biofuel producers with an economically viable and long term, environmentally friendly solution.

Doing business in Ukraine and other countries is significantly different. This also applies to the bioenergy sectors. Compared with European and American models, which provide for the development of cooperative forms of business, Ukraine has a large-scale development of vertical integration. The latter is manifested not only in the merger of the companies located at the bottom (or back down integration) or above (up or forward integration) the process chain, but also to develop a new development strategy for the group of companies, including energy independence.

The research indicates that identical processes of building a business in the agro-bioenergy sector take place in the EU and the US. The cooperation model provides for joint efforts of farmers with the aim of self-sufficiency and the implementation of energy resources that are not under the force of each farmer individually.

Diversification as a biofuel production process is a feature of small and medium farmers (the EU, US and Ukraine) and agricultural enterprises (Ukraine). In this case, farmers focus on waste management and energy autonomy.

There are two worldwide spread biofuels: biodiesel and bioethanol.

4.1. Biodiesel production

The world's largest producers of biodiesel in 2015 are (mln m^3): the USA – 4.8; Brazil – 4.1; Germany – 2.8; France – 2.4; Argentina – 2.1 [47].

In Argentina, the average production of biorefinery is 70.789 thousand m^3 per year. The largest ten companies cover over 70 per cent of the country´s total capacity. They are international and export their production. The majority of large biodiesel plants are fully vertically-integrated. 28 small companies have the average capacity of 28.82 thousand (from 12 to 110) m^3 per year. They buy feedstock for the market price and, therefore, have a higher production cost. The Government of Argentina gives priority to nonintegrated small producers. According to the new price scheme for biodiesel, large companies (production over 100 thousand tons a year) have the price by

22.7% less than a small plant (production up to 20 thousand tons a year) [4].

One of the world leaders in biodiesel production is Malaysia. Here, palm oil is used as a raw material. Its yield is 3.93 t/ha. The vertical integration of palm biodiesel production is considered as a way forward. It gives the opportunity to reduce operation cost [31].

In EU, biodiesel plants are mainly single plants. For example, in Germany, only two plants (with the total capacity of more than 200,000 tons per year) are so-called annex plants that are connected to oil mills and may be called integrated. They process exclusively rapeseed oil. While a smaller number of biodiesel plants use other oils: palm, cooking oils, animal grease etc. Oil mills and biodiesel plants have long-term contracts with their clients and suppliers. Also, they may be engaged in the international market [42].

For the large-scale biodiesel plants, farmers are only raw material suppliers. Only small-scale biodiesel plants are operated by farmer cooperatives. For example, there is a cooperative "SEEG Südsteirische Energie- und Eiweißerzeugung reg.Gem.m.B.H." (Austria). It was founded by 580 farmers. Its main target was to produce biodiesel (the production capacity is 10 million liters of biodiesel per year). The main customers of SEEG are farmers, local authorities, and petrol stations [9].

In the USA, biodiesel producers, as a rule, are not integrated in crop growing. They utilize integrated procurement, distribution, and logistics network to convert feedstock into biofuel [61].

4.2. Bioethanol production

The world largest bioethanol producers in 2016 are, million m^3: the USA – 58.1; Brazil – 27.6; EU – 5.2; China – 3.2; Canada – 1.7 [54].

In the USA, a significant share of bioethanol plants is owned by farmers' cooperatives. Bioethanol production cooperatives build a technological vertical but do not create an organizational one. Bioethanol plants require cheap feedstock. That is why they strive to reduce transportation cost. For example, in the USA farmers are located within an 80 km radius to keep transportation costs low [7]. So in this country, the production of corn bioethanol is a non-vertically integrated market. As a result, bioethanol producers pay market prices for corn. In Brazil, vice versa, bioethanol producers own sugarcane plantations and production is more vertically-integrated. As a result, the overall production cost of ethanol in the USA is approximately 65 % higher [21]. However, one of the largest bioethanol producers of the USA, Green Plains Inc., is a fully vertically-integrated company [49].

The low degree of upstream integration results in feedstock supply risk. Food processors strive to a high level of security feedstock supply. They also integrate into downstream activity (blending and market access). The farmers, farmer cooperatives and agricultural commodity traders are venturing into bioethanol manufacturing, but they avoid downstream integration [14].

So, there are three possible ways of integration in biofuel sector (*Figure 3*).

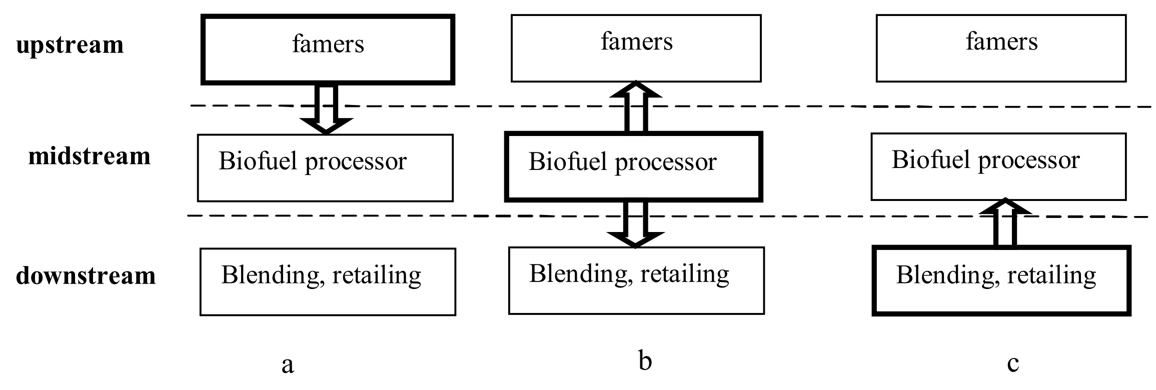

Fig. 3. Possible ways of vertical integration

To increase economic efficiency, bioethanol plant must utilize all by-products, including carbon dioxide. For example, Crop Energies Bioethanol GmbH [55] operates one of the largest bioethanol plants in Europe. Its annual capacity is 400 thousand m^3 of bioethanol. Moreover, the plant produces liquefied carbon dioxide – 100 thousand tons per year. It is a valuable product and it is used in the food industry [55].

4.3. Vertical integration in biogas production

Let us consider the feasibility of biogas production and its utilization in vertically integrated companies. The world largest producers of biogas are, billion m^3: China – 15.2; Germany – 13.13; the USA – 12.3 [28].

4.3.1. Ways of biogas utilization

The economic efficiency of biogas production depends on the way of its utilization. It can be used to meet the needs in some energy resources:

- substitution of natural gas;
- generation of electrical power;
- co-generation (combined heat and electric power);
- substitution of conventional transport fuels (gasoline and diesel fuel).

A number of various co-products (e.g. biofertilizers) are produced in biogas plants. The upgrading of biogas emits biomethane and carbon dioxide. The reserve of economic and environmental efficiency of biogas plants is utilization of carbon dioxide contained in biogas [24]. Now, there is a progress in this way. One of the first biogas plants to utilize carbon dioxide is Ecofuels – a joint project of some companies in the Netherlands. The carbon dioxide is utilized in horticulture to increase yield [22].

Utilization of carbon dioxide can increase the total income of biogas plant. For example, in Ukraine (December 2016), its wholesale price was USD 927.64/1000 m^3 [13]. So, carbon dioxide can be sold to increase the efficiency of both a biogas plant and a vertically-integrated company. An organic fertilizer can be sold, but it has a low price.

Table 2.
The cost of energy resources and by-products produced out of one thousand cubic meters of biogas

The ways of biogas use	Cost, USD/1000 m^3		Rating
	Without the carbon dioxide sale	carbon dioxide sale	
Substitution of natural gas	166,60	537,66	4
Generation of electrical power	151,02	522,08	5
Cogeneration	231,17	602,23	3
Substitution of gasoline A-95	541,00	912,06	1
Substitution of diesel fuel	437,11	808,16	2
The ratio of maximum value to minimum one	3,10	1,75	-

The calculations show that the greatest income from biogas utilization as motor fuel can be achieved. The by-product (especially carbon dioxide) utilization will enhance economic efficiency (*table 2*). The official currency rating of the National Bank of Ukraine [63] was used in the above calculation.

The production cost of biogas depends on the substrate and the technology. It varies from USD53/1000 m^3 to USD120.5/1000 m^3 [62]. The ratio of the resulting energy cost to the production cost of biogas is much higher when a gaseous biofuel is used to replace a conventional motor fuel. Market prices determine which co-product will be produced. Utilization of a co-product (carbon dioxide) improves the above ratio (*table 3*).

Table 3.
The ratio of the produced energy cost to the production cost of one thousand cubic meters of biogas

The ways of biogas use	Ratio		Rating
	Without the carbon dioxide sale	carbon dioxide sale	
Substitution of natural gas	1,46	4,7	4
Generation of electrical power	1,32	4,56	5
Cogeneration	2,02	5,26	3
Substitution of gasoline A-95	4,73	7,97	1
Substitution of diesel fuel	3,08	7,06	2
The ratio of maximum value to minimum one	3,58	1,95	-

One thousand cubic meters of biomethane substitutes 1060 liters of gasoline and 919 liters of diesel fuel. Therefore, the adjusted costs of biomethane to substitute conventional motor fuels are, USD/m^3: gasoline – 217; diesel fuel – 250. The calculations indicate that exploitation of biogas plants is reasonable. Their usage decreases costs of energy resources applied by 27…75 %. The comparison of efficiency of energy producing in vertically-integrated companies with the use of biogas plant is listed in Table 4.
Sweden has experience in biomethane usage as motor fuel. In this country, around 54% of biogas is upgraded to vehicle fuel. Its cost is 5…31 % cheaper compared with compressed natural gas [59]. That is why biomethane is a prospective transport fuel.

4.3.2. Vertical integration in biogas production

The largest shares of agricultural biogas production are in Germany and Denmark (*table 5*) [10; 23].

Table 4.
Comparative effectiveness of production and purchase of energy resources

Technological production chains	The cost of energy resources*				
	Electric power, USD/100 kWh.	natural gas (biogas) USD/1000 m^3	heat, USD/GJ	Fuel, USD/m^3/biomethane, USD/1000 m^3	
				gasoline A-95	diesel fuel
Agricultural enterprise					
Production cost (biogas component):					
- electric power	4.38-6.16				
- heat			119.6		
- biogas		53.0-120.5			
- biomethane		162-230		217*	250*
Market price					
- electric power [64]	7.31-8.77				
-natural gas [65]		318.28			
- heat [66]			213.6		
- gasoline A-95 [67]				860	
- diesel fuel [68]					760
Deviation, % (+/-)	-(29…40)	-(27…49)	-44	-75	-67

*Adjusted price

Table 5.
The share of agricultural biogas plant production in total biogas production (2015)

Country	Number of plants in agriculture	Energy production, GWh/year	Share of total production, %	Primary utilization type (%)
Brazil	60	1096	28.6	Electricity (77)
Denmark	65	1115	72.5	Electricity (77)
France	267	1039	32.7	
Germany	8005	42863	85.8	Electricity (58.1)
Sweden	39	44	2.5	Vehicle (54)
United Kingdom	163	-	13.2	-
USA	239	26992*	39.2	electricity
China		11200**	12.5	
Poland	45	1091	39.1	CHP (100)
Ukraine	8	-	47.0	CHP

*Calculated based on statistics.

**Agricultural biogas plants only, except rural biogas plants.

Source: developed by the authors on the basis of [10; 32; 44; 58]

Different business models of biogas production are used in agriculture. In the EU, farm-scale and centralized biogas plants are used primarily. There are a lot of cooperatives, too.

The issues of renewable energy resources are paid much attention from both research organizations and businesses. In Ukraine, during 2012-2015 a number of vertically-integrated agrarian companies have implemented innovative solutions associated with the reduction in dependence on suppliers of natural gas, heat and electricity. For example, an agro-industrial holding "Astarta-Kiev" has put a biogas pipeline into commercial operation. It has joined a biogas plant with Globinskiy sugar factory and Globinskiy soybean mill. Biogas replaces up to 50% of the demand of Globinskiy sugar factory in natural gas and up to 90% of the demand Globinskiy processing plant (soybean). The company plans to build biogas plants at other sites [18; 70].

According to Ms. Victoria Kapilyushna (financial director of Mironovsky Hliboproduct), the introduction of a biogas plant contributes to strengthening the vertical integration of the company, optimizing production costs and increasing energy independence [46].

In Ukraine, a number of biogas plants are operated by integrated agro-industrial companies. Internationally, vertically-integrated agricultural and food processing companies operate biogas plants to solve their ecological and energy problems (*Table 6*) [15; 40; 44; 45]. As substrates they use both energy crops and manure. A typical vertical integration of biogas plant into agro industrial company in Ukraine is shown in *figure 5*.

Table 6
Integrated biogas plants in agriculture and agro food industry

Country	Place (company)	Arable area, ha (livestock)	Substrate, t/day	Utilization	Plant capacity, nm^3/h
Ukraine	Oril-Agro, Mironovsky Hliboproduct	355000 (30 mln heads of poultry)	Poultry manure (140) + sorghum silage (80)	CHP	3000
	Globino Sugar plant, Astarta – Kyiv agri industrial holding	205000	Silage + bagasse (328)	heating	6250
	Pig farm, Danosha	12000 (55000 pigs)	Pig manure (245)+ corn silage (27)	CHP (1063/1086)	542
	Dairy farm, Ukrainian dairy company	14000 (4000 cows)	Manure (400)	CHP (625/-)	265
	Pig farm, Agro-Oven	16000 (15000 pigs)	Manure (80)	CHP (160/320)	137
	Rokitne Sugar mill LLC, Silgosp-product	25000	Bagasse, corn and sorghum silage	CHP (2250/)	900
Poland	Koczala, Poldanor S.A.	15000 (18,000 sows)	Manure (55000 t/year), corn silage (25000 t/year), glycerine (10000 t/year)	CHP (2126/2206)	1036
	Uniechówek, Poldanor S.A.	15000 (18,000 sows)	manure 36 500 t/year, corn silage. 17 520 t/year	CHP (1063/1081)	518
	Strzelin, Südzucker Polska S.A.	396000	Beet pulp	CHP (2000/2065)	1300
Netherland	Suiker unie		Beet pulp, organic waste	biomethane	2500
Hungary	Magyar Cukor Zrt., AGRANA group	-	Beet pulp	heating	8000
China	Huishan Dairy Group	(180,331 dairy cows)	Manure	CHP (5.6)	3500

Source: developed by the authors on the basis of [15; 40; 44; 45].

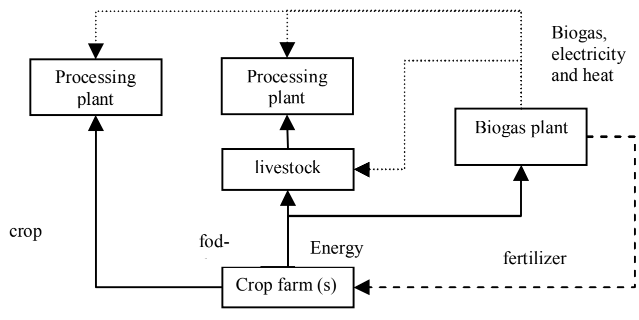

Fig. 5. Biogas plant integration in Ukrainian agro-industrial holdings

In Ukraine, biogas plants of vertically-integrated agro-industrial holdings primarily work to meet corporate energy requirements, while in the EU, biogas plants, as a rule, supply external consumers with energy resources. Thus, the implementation of biogas technologies remains the stuff of agribusiness leaders that have their own resources to work in a weak financial market and a lack of investment [18].

Biogas systems in agriculture have a number of features. Firstly, they cannot exist apart from the farms or processing plants, which are a source of organic waste and raw materials. The distance between them should not be too large to reduce transportation costs. For example, in Denmark, the distance does not exceed 11 km. If a company cannot get a "green tariff", biogas system works to meet their own energy requirements. Besides, the abovementioned scheme takes place on livestock farms or processing plants.

The major biogas producers have their own organic raw materials. These are farms, food processing facilities, distilleries etc. Besides, some energy companies enter the biogas producing business. As a rule, they build a vertically integrated corporate structure (*Table 7*). As to company-integrator, it should be noted that some of them are not actors of agriculture or agro food industries. For example, the main activities of Bioenergy Project Sp. z o.o. are Electric Power

Generation, Transmission and Distribution [16]. The main activity of Eko-Energia Grzmiąca Sp. z o.o. is power engineering [8].

Table 7.
Biogas producing companies

Company	*Country*	*Annual biogas producing, GWh*
Verbio AG	Germany	480
Agri.Capital Group	Germany	380
Swedish Biogas International AB	Sweden, Finland	650
Scandinavian Biogas	Sweden	54
NGF Nature Energy	Denmark	238
Bioenergy Project Sp. z o.o., Konopnica	Poland	48
Eko-Energia Grzmiąca Sp. z o.o., Grzmiąca	Poland	39
Synergy Biogas, LLC	USA	22

Source: developed by the authors on the basis of [1; 8; 16; 17; 29; 43; 56; 57]

In the world, there is the following practice: a company-supplier of technological equipment and farmers (supplier of organic raw material) set up a biogas producing company. For example, CH_4 Biogas formed Synergy Biogas, LLC to build, own and operate a biogas facility at a Synergy Dairy that will produce renewable energy from manure and substrate [43].

Some companies set up a producer of different renewable energy resources. For example, VERBIO AG (Germany) is a large producer and provider of biodiesel, bioethanol and biomethane. The nominal annual capacity is: biodiesel – 450,000 tons; bioethanol – 270,000 tons; biomethane – 480 GWh. Moreover, all by-products of biofuels and biomethane production are utilized. The company is implementing the strategy of vertical integration to strengthen its market position [56].

4.4. Combined production of different biofuels

Food industry companies are introducing the technology of recycling organic waste at biogas plants. This trend is particularly noticeable in ethanol plants. In Ukraine, the pilot plant for the production of biogas with the capacity of 1,000 m^3 per day was introduced to the State Enterprise "Luzhansk Experimental Plant" in 2008 [69]. Biogas production is carried out from vinasse, which is a waste product of alcohol production. Stillage is a byproduct of ethanol production and the deteriorating environmental state in the field of distilleries location. Thus, the production of biogas from vinasse solves both energy and environmental problems.

In this business segment, biogas plants were implemented in distilleries in several countries (USA, Germany, Poland, Lithuania, China, and Ukraine) (*Table 8*). This evolution is positive and reflects both the reduction of energy dependence on suppliers, and environmental responsibility.

Table 8.
Biogas plants integrated in ethanol plants

Country	**Location**	**Feedstock**	**Biogas production, nm^3/day**	**Electric/heat power, kW**
Ukraine	Luzhansk Experimental Plant	Vinase (300 t/day) + silage (25 t/day)	13000	430
Lithuania	Bioethanol plant Kurana		25 million nm^3/annual	4000/12000
Poland	Allter Power Biogas plant	Stillage, manure, beet pulp (84,000 tonnes/year)	6.0 nm^3/year	
Germany	Verbio Ethanol GmbH & CO. KG (Zörbig), Verbio AG	Stillage (ethanol capacity 100,000 t/year)	2,500 nm^3/h	CHP
China	Tianguan Group Co., Ltd	Stillage (ethanol capacity 600,000 t/year)	454,000 (150 million nm^3 per year)	36 MW

Source: developed by the authors on the basis of [2; 39; 48; 56; 69]

Microalgae are a potential source for biodiesel production. They have a higher growth rate than terrestrial plants. But large-scale application of the above raw material is limited by the availability of carbon dioxide [33]. Production of one ton algae requires 1.8 tons carbon dioxide [53]. Bioethanol plants may be used as a source of carbon dioxide for biodiesel production. Brazil is set to build the world's first algae-based biofuel plant. It converts seaweed into biofuel (around 1.2 thousand m^3 annually). The facility is built on an ethanol plant [12].

5. AGRO-ENERGY VERTICAL AND INDICES OF VERTICAL INTEGRATION

In the agrarian sphere of the economy, large-scale production of biofuels was formed and began to develop. Therefore, we suggest introducing such a notion as the agro-energy vertical. **The agro-energy vertical** is a vertically integrated corporate structure in the agricultural sector of the economy that unites the entire production cycle from the production and receipt of organic raw materials to its processing into energy resources.

The general scheme of the agro-energy vertical is given below (*Figure 6*).

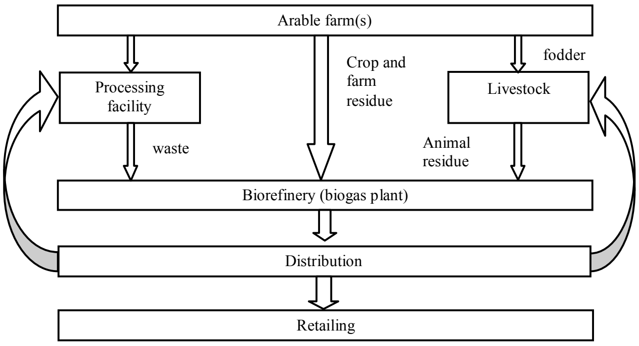

Fig. 6. General scheme of the agro-energy vertical

The two types of the energy vertical have been selected. The first type is accepted mainly for biofuel (bioethanol and biodiesel) producers. Nowadays, some companies started business in biogas production, too. The main aim of the above company is to produce biofuels for external consumers (*figure 7, I*). The same scheme is applied by farms and farm cooperative biogas plants in Germany. But they have a higher output/input energy ratio compared with biofuel production.

The second type (*figure 7, II*) is production of biofuel (biogas) primarily to meet their own energy requirements. As a rule, this type of energy vertical is typical for production and utilization of biogas. According to our calculations and existing practice, the second type of vertical integration transfers up to 20% of total energy potential of biogas to external consumers.

Operation of biogas plants can improve a number of indicators of economic activity. Commissioning of the biogas plant changes the index of vertical integration too [50-52]. To measure vertical integration, common indices are used [38]. Moreover, vertical integration can be considered to be a management style which brings large part of the supply chain not only under a common ownership but also into one corporation (producing its own energy resources instead buying them from suppliers).

Commissioning of biogas plant allows agrarian companies to change the index of vertical integration. It may be measured by the distribution of cash (material flows) between the structural divisions of a company to the total flow. It ranges from 0 to 1.

An own biogas plant may meet (full or partly) the requirements in energy resources (motor fuel, electricity, thermal energy, organic fertilizers). It will reduce the use of external flows of material resources. So, to measure the vertical integration, we suggest using an index [34]:

$$IEVI = \frac{\sum_{i=1}^{n} ER_i}{MRC}, \quad (2)$$

where MRC - the cost of material resources necessary for the operation of agrarian formation (fuels, lubricants, electrical and thermal energy, mineral fertilizers, seeds, plant protection, etc.); ER_i - gross income from the production i^{th} energy resource or a by-product of the biogas plant; n - number of types of energy and material resources.

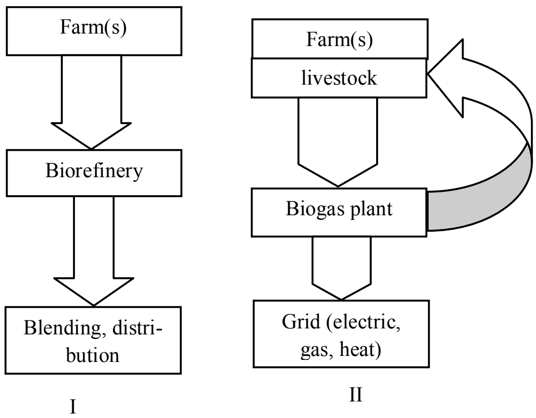

Fig. 7. Agro-Energy vertical: I - first type; II - second type

Electricity generated by a co-generator (generator) can be sold to a common grid for "green tariff". It increases the gross income. To meet the requirements in energy resources, a farm (agricultural company) can buy it for market prices. It enhances the index of vertical integration. So, the formula (2) may be transformed in the following way

$$IEVI = \frac{\sum_{i=1}^{n} \left(\lambda_i \cdot ER_i\right)}{MRC}, \quad (3)$$

where λ_i is the adjusting factor for i^{th} energy resource.

The factor λ_i is calculated as

$$\lambda_i = \frac{GT_i}{MT_i}, \quad (4)$$

where GT_i - "green tariff" for i^{th} energy resource; MT_i - market price of i^{th} energy resource.

The index of vertical integration, calculated by authors, for some companies equals, %: Astarta-Kiev – 46; Ukraine Dairy Company – 87; Terezyne, JSC – 32; Luzhansk Ethanol Plant – 32.

6. CONCLUSIONS

The sixth sphere of the agro-industrial complex (bioenergy production) has been formed.

An important condition for growth of profitability is decrease dependence from external supplying by energy resources (natural gas, electricity, heat, gasoline, diesel fuel, etc.). That is why, now there is a tendency of biogas production integration in agriculture and agro-food industry.

There are vertically-integrated and not integrated biofuel production models. It depends on the national legislation. Biofuel production is more integrated in Brazil and Argentina.

Producers of some kind of biofuels and biogas are appearing in the market.

The prospective way of vertical integration is a combination of some level of energy production: bioethanol-biodiesel and bioethanol-biogas.

The integration in the production of biogas has its own characteristics. If there is no proper incentive system, agricultural companies build biogas plants to meet their own energy needs. In the opposite case, biogas and biofuels are produced for the market demands.

Energy companies implement an integration strategy for the production of biomethane, electricity or thermal energy to meet the market needs.

On the basis of the research conducted, we proposed to introduce the concept of the agro-energy vertical. It includes three segments: organic raw material supply (energy crop growing and/or livestock waste); biofuel(s) (biogas) production; marketing and distribution. The energy vertical is strengthening the vertical integration, optimization of production costs and increases the energy independence of a company. The two types of the energy vertical have been selected.

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ASPEKT ENERGETYCZNY INTERGRACJI WERTYKALNEJ W ROLNICTWIE

Słowa kluczowe*:* rolnictwo, energia, biopaliwo, biogaz, integracja

Streszczenie. Artykuł bada aspekty energetyczne rolniczych przedsiębiorstw zintegrowanych. Badania dowodzą, że integracja w zespołach rolniczo-przemysłowych powinna być postrzegana szerzej włącznie z produkcją bioenergii. Opracowano wykres relacji w ramach integracji wertykalnej. W badaniach porównano wydajność wertykalnie zintegrowanych i niezintegrowanych przedsiębiorstw. Gospodarstwa rolne i przedsiębiorstwa rolno-spożywcze starają się zredukować zależność energetyczną. Na postawie badań, zaproponowano nową, naukową definicję: przedsiębiorstwo agroenergetyczne lub agroenergetyczny pion. Dla przedsiębiorstwo agroenergetycznego rozważano sposoby integracji wertykalnej i horyzontalnej. Zaprezentowano autorską wizję wykonalności produkcji alternatywnych paliw. Wydajność produkcji biogazu i jego wykorzystanie (również jako produkt uboczny) została wyliczona. Dowiedziono, że użycie produktów ubocznych zwiększa zyskowność produkcji biopaliwa.

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