INSTITUTE OF AGRICULTURAL
AND FOOD ECONOMICS
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From the research on socially-sustainable agriculture (18)

Zbigniew Floriańczyk
Joanna Buks
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COMPETITIVENESS OF THE POLISH FOOD ECONOMY UNDER THE CONDITIONS OF GLOBALIZATION AND EUROPEAN INTEGRATION

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dr Zbigniew Floriańczyk
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Affiliations:
Zbigniew Floriańczyk, Ph.D. – the Institute of Agricultural and Food Economics – NRI,
Joanna Buks, MSc – the Institute of Agricultural and Food Economics – NRI,
Grzegorz Kunikowski, MSc – Institute for Renewable Energy

The work was conducted under research topic **Competitiveness of sustainable agriculture,** within the task *Productivity of different forms of sustainable agriculture.*

The aim of this paper is to present sustainability of agriculture in the context of its multifunctionality and productivity. The analysis covers the issues of agriculture's share in the production of renewable energy, current technology of conversion of agriculture based raw material into renewable energy production and the economic performance of potentially sustainable farms.

Reviewer
Robert Garay, Ph.D., Research Institute of Agricultural Economics in Budapest

Proofreader
Joanna Gozdera

Technical editor
Joanna Gozdera

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Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej
– Państwowy Instytut Badawczy
ul. Świętokrzyska 20, 00-002 Warszawa
tel.: (22) 50 54 444
faks: (22) 50 54 636
e-mail: dw@ierigz.waw.pl
http://www.ierigz.waw.pl

Contents

Foreword

The presented study is a continuation of the research work in the series "From the research on socially-sustainable agriculture" that emphasises economic, social and environmental spheres of sustainability. This study is carried out in the framework of long-term research program "*The Competitiveness of the Polish Food Economy in the Era of Globalisation and European Integration*" implemented by the Institute of Agricultural and Food Economics, National Research Institute (IAFE-NRI) in Poland in the years 2011-2014. Namely, the work undertaken on the productivity of Polish agriculture in the function of delivering raw materials for agro-food products and renewable energy are part of a research task "The productivity of various forms of sustainable agriculture". The expected result of this research topic will be identification of mechanisms that determine the productivity of Polish farms, depending on their level of sustainability and farm type. The results of this research will be used in turn to assess the competitiveness of sustainable agriculture and support policy aiming at long-term development of Polish agriculture.

The study covers issue related with sustainability of agriculture in the context of production of renewable energy and economic performance of potentially sustainable farms. The study underlines role of interactions between food and energy productions, strategic documents and modern technologies of energy production based on renewable agricultural resources on involvement of Polish farms in the production of raw materials for energy.

A special feature of the study is utilisation of different research centres research results specializing in the issues of agriculture impact on the environment and technological aspects of agricultural production for energy purposes. In the study the potential increase of the involvement of specific groups of farms in the production of biomass for energy is determined by ability to adapt specific technologies and optimal allocation of farm resource. Among the farm resources special attention is put on agricultural land. A limited area of land, together with the increasing pressure on the non-agricultural use means that it becomes the most important factor limiting agricultural growth opportunities in the long term. Therefore sustainable crop rotation practices to maintain natural productivity of agricultural land are considered main characteristic of farm sustainability.

Similarly diversification of farms is recognised as one of the elements of agriculture sustainability. Coexistence of various forms of farms increases optimal utilisation of diverse resources of rural areas and provision of specific economic and social functions. From other side different forms of farms have predisposition to specialize (or not) in different directions of production.

The institutional arrangements for the development of agricultural production and the share of this sector in the production of renewable energy sources underline key role of technologies development to insure sustainability of agriculture production. Sustainability refers here to efficiency of energy production based on agricultural resources, positive impact of this production on natural resources and food security. In this light, the total productivity of the various forms of farms depends on the proper allocation of resources to the various lines of production.

In respect to different functions of agriculture the priority is given to food production. This indicates that the development of production for energy purposes is connected primarily with marginal soils and natural resources conservation. Authors argue that technological solutions in the field of biofuels production and related institutional arrangements indicate future directions of this type of production development. Adaptation of proper technologies to particular groups of households resources should be considered as the basis for overall farm productivity assessment.

1. Agriculture productivity from the perspective of the food and renewable energy production

The complexity of the evaluation of agricultural productivity is determined with multiple impact of agriculture on the economy, environment and society, especially from local and regional communities perspective. This is due to the different perception of the agriculture role depending on the level of generalization from the economic, social or spatial perspective. The economic importance of agriculture is traditionally seen through the prism of provision of food and raw materials for industry.

The general rule here is declining importance of agriculture with economic growth. However, this tendency has a relative character and reflects relatively higher dynamics of growth of non-agricultural sectors in comparison with agriculture. Demand for new consumer products and services from industry tends to be more flexible than the food. As a consequence, once the agriculture production level has reached the basic food needs, the main demand factors determining the rate of growth in agriculture are extinguished. It should be noted that this regularity is relative and primarily refers to the total amount of consumer spending. As incomes rise, one can expect changes in the structure of expenditure on food. Most often this leads to an overall increase in demand for food products with a higher added value[1]. The industry's demand for raw materials of agricultural origin depends on the degree of competitiveness of the alternative raw materials usually based on minerals. In this case, you can (simplifying) say that the equilibrium is established on one hand by the level of agriculture production capacity and on the other – the exploration of available mineral resources.

Preservation of the natural potential of agricultural production and its interactions with the environment reflect the degree of sustainability of farming in the area of environmental sustainability[2]. The ecological balance in the area of sustainability together with economic and social sphere is a starting point of an

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[1] Świetlik K., *Ceny żywności w procesie rynkowych przemian polskiej gospodarki (1994--2004)*, Studia i Monografie nr 141, IERiGŻ-PIB, Warsaw 2008.

[2] Borys T., *Wskaźniki zrównoważonego rozwoju,* Wydawnictwo Ekonomia i Środowisko, Białystok 2005.

overall assessment of the sustainability of farm[3]. The basic problem is to determine the features to be included in the objective function, and to set the threshold values for these variables[4]. Determination of threshold criteria relate primarily to environmental and social objectives on the assumption that market factors determine the balance in the economic sphere. Farms with higher levels of sustainability in environmental and social spheres participate in a small part of agricultural production, which justify search for answers to the question about the possibility of increasing this population and its ability to meet food and economic needs of the whole society. Comparison of the productivity level of sustainable forms of farms with conventional farms brings the answer to this question.

The study of productivity of different forms of farms allows for comparison from one side, the efficiency of their management and on the other side level of farm resource utilisation[5]. In the static evaluation of the productivity of different groups of farms outcomes have signal meaning. This allows for identification of farms predisposed to achieve the best results and for assessment of the impact of selected agricultural policy measures on farm. Differences in the structure and production profile, capital, equipment and the amount of labor characterise different production technologies. Economic evaluation includes input and output characteristics that are subject to market valuation. From other side the amount of expenditure incurred in the restoration of natural resources is one of the manifestations of the interaction with the environment. These links are bidirectional because on the one hand the quality and quantity of natural resources directly determine the amount of agricultural production. On the other hand, farm activities directly affects the quality and volume of natural resources. Currently expenditures incurred to maintain the potential of the natural resources are directly recorded in economic calculation. The positive effects related to such activities are in turn distributed over time making them difficult to meas-

[3] Matuszczak A., Koncepcja zrównoważonego rozwoju w obszarze ekonomicznym, środowiskowym i społecznym, Roczniki Ekonomiczne Kujawsko-Pomorskiej Szkoły Wyższej w Bydgoszczy, nr 2, Bydgoszcz 2009.
[4] Zegar J, Z badań nad rolnictwem społecznie zrównoważonym (11), Raport PW nr 11, IERiGŻ-PIB, Warsaw 2011, s. 3.
[5] Floriańczyk Z., Buks J., Toczyński T., *Z badań nad rolnictwem społecznie zrównoważonym (14). Zagadnienia produktywności w strategiach rozwoju i jej pomiar w odniesieniu do gospodarstw zrównoważonych*, Raport PW nr 27, IERiGŻ-PIB, Warsaw 2011.

ure. Recorded differences in technology, however, allows for capturing the potential to meet sustainability of production on individual farm level. In particular, comparison of the productivity of various farm groups allows for identification problematic groups, taking into account their degree of sustainability. The key parameter of sustainability here is to promote the maintenance of the production potential of agricultural land resources[6].

As regards sustainability of agricultural production form the viewpoint of preservation of agricultural land in the conditions of the European Union the regulations are used to indicate the desired agricultural practices. Usually they define the boundary conditions of farming. Compliance with specified boundary conditions is related to the reorganization of production, which has usually negative impact on the economic performance of the farm. Lost profits resulting from deviations from the economic optimum is offset here by direct transfers. Another path leading to the development of sustainable farm production is change in production technology. At the same time sustainable technologies should imply productivity that allows for the realization of basic functions of agriculture, particularly in the production of raw materials for processing sector and industry. Sustainable technologies are associated with reduced use of inputs such as fertilizers and pesticides. As an alternative to intensive use of the means of production of industrial origin agro-technical practices are preferred, aiming at raising natural productivity of agricultural land. Among them use of proper crop rotation that is leading to preserve the natural productivity of agricultural land is most welcome[7].

Generally, industrial agriculture is considered as having negative impact on environmental resources. That is justified, among others, by significant share of agriculture in greenhouse gas emissions. Reduction of the negative impact of agriculture on natural environment is therefore linked with increased involvement of agriculture in the production of biomass for energy purposes. However, competitive nature of agricultural production for energy purpose to food production is treated as a fundamental limitation in the development of this type of production.

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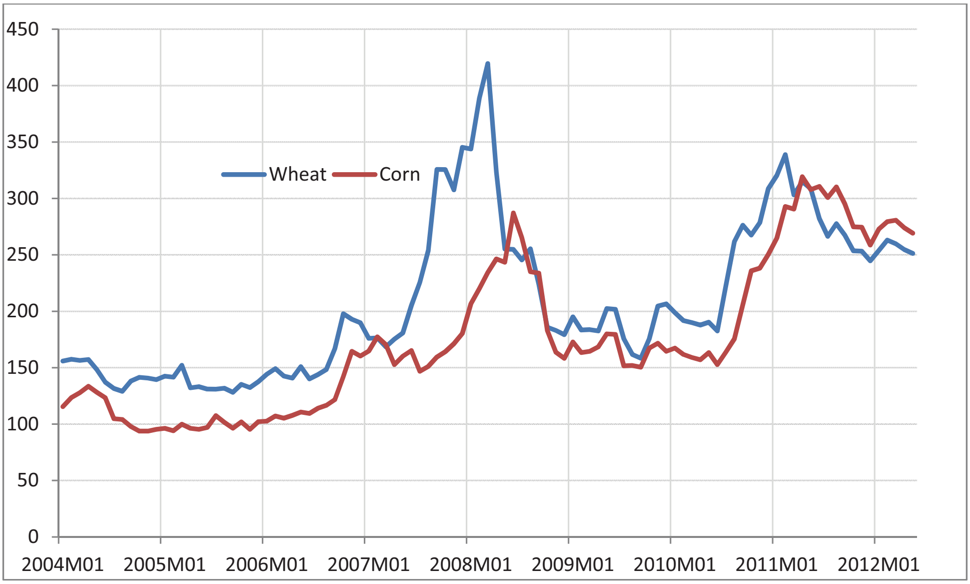
[6] Buks J., *Czynnik ziemi jako element zrównoważenia rolnictwa*. Roczniki Naukowe SERiA, t. XIV, z. 1, Białystok 2012, s. 82-87.
[7] Ibidem.

1.1. Impact of agriculture involvement in the production of renewable energy on the food market – a global approach

The relationship between development of biofuels and agricultural prices was pointed out in the biofuel market analysis conducted by J.P. Morgan Securities Inc[8]. The investigation was based on the data from companies involved in the production of biofuels and recorded on the capital market. Results indicated a high unprofitable investments in this sector, together with an increase in prices of agricultural products. Analysis of the economic accounts of these companies showed that by mid-2008 production of bioethanol was characterized by gross profitability of 70%. The sharp growth of prices of agricultural products at the end of that year caused that the profitability of most companies was negative. Long-term analysis showed that the high rate of development of biofuel production in the United States was primarily driven by increase in yields of corn. On the other hand high prices of fossil fuels has increased the interest in investments in the biofuels sector and the dynamic growth of the production of bioethanol. The strong rise in prices of agricultural products and natural gas in 2007 and 2008 led to a decline in the profitability of the production of bioethanol. It is estimated that the introduction of production quotas would prevent excessive investment in the biofuel sector based on short-term market development. Thus regulation would contribute to the stabilization of the production structure and use of agricultural land.

[8] Based on presentation at Agriculture Forum Global Agriculture & Rural America in Transition, Washington, 21.02 – 1.03 2009.

Figure 1. Development of corn and wheat prices as a response to bioethanol production and trade distortions



Source: World Bank data.

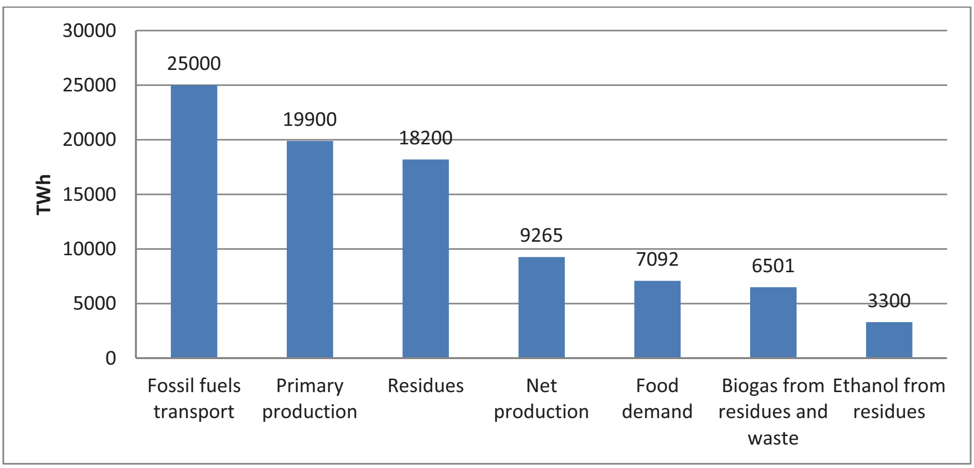
The strength of the impact of increased agricultural resources involvement in the production of biofuels on food market describes study conducted by Harry de Gorter[9]. The investigation was devoted to the relationship between the U.S. biofuels market and rising prices of agricultural products in recent years. Statistical analysis of development of prices of energy and agricultural products showed a strong relationship between the dynamics of the prices of these two groups of products. In the study the impact of shocks affecting the fluctuation of market prices of agricultural products of a natural and speculative character were eliminated. A key determinant of the development of the biofuels market appears to be a policy that supports this type of production. As a result, biofuel support policies can be responsible for strong increase in the price of corn that was partly used for bioethanol production. The consequence of increased corn prices were rising prices of wheat as a complementary product for corn.

[9] de Gorter H., *Biofuels and commodity markets,* International Scientific Days Conference, Faculty of Economics and Management, Slovak Agricultural University, Nitra Slovakia, 16 May 2012.

The author, Harry de Gorter, also pointed to the dependence of the growth in demand for renewable energy that uses raw materials of agricultural origin of energy prices on the world market. According to the researcher next to the policy that promote the production of bioethanol, a strong increase in demand for corn in recent years was stimulated by the rising oil prices. As a result of the improper institutional arrangements and market development a rapid interest in using corn to produce biofuels resulted in higher prices of basic foodstuffs, especially based on corn and its direct substitutes.

Similar conclusions about the limited opportunities to expand agricultural production in the field of raw materials in order to meet energy demand in the transport sector formulated the research team led by Kersti Johansson[10]. The study compared the size of global agricultural production destined for food production expressed in energy equivalent with normative demand for food.

Figure 2. Potential amount of energy by source of origin



Source: Johansson K., Liljequist K., Ohlander L., Aleklett K., Agriculture as Provider of Both Food and Fuel, AMBIO (2010) 39, p. 95.

[10] Johansson K., Liljequist K., Ohlander L., Aleklett K., *Agriculture as Provider of Both Food and Fuel*, AMBIO (2010) 39, s. 91-99.

The conversion rates of agricultural production to the production of ethanol, biodiesel and biogas were used to calculate the potential production of renewable energy from agriculture. The study took into account loss of production associated with the transportation and storage of raw materials for food production as well as being part of the crop production input in agricultural production (seed and feed) to the calculation of the net production. Comparison of demand for food in the energy equivalent – 7 092 TWh as optimistic and – 9 262 TWh as pessimistic scenario with – 7 225 TWh of output indicated that the balance can be only achieved in the lower range of food demand. Researchers have pointed to the possibility of the use of losses and waste products for the production of renewable energy.

According to the estimates utilisation of residues and waste products would provide up to one quarter of demanded by transport fuels in the energy equivalent expression. In summary, the researchers underlined possibility of maintaining relative stability in the food market. In case the production of energy is based on non-competitive to the food production raw material and marginal soils for biomass production is used one could expect stable food prices. An important limitation of the investigation was assumption on stability of structure of the demand side for plant and animal products. As a result, the authors omitted forecasts of changes in the global consumption that showed the growing imbalance between supply and demand for food due to global consumption patterns changes.

Analysis and forecasts of the global food market development based on IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade) show the weakness of the analysis which implies stability of the food market. In the model of basic food supply most important production constraints are distinguished as climate change, water resources, technological progress and the implementation of the achievements of agricultural science nature[11]. The growth of demand for food is generally associated with an increase in population and income, the process of urbanization of societies and the demand for biofuels. In this model, food prices are recorded on an annual basis and

[11] *Agricultural Projections to 2021*, United States Department of Agriculture, Long-term Projections Report OCE-2012-1, February 2012 oraz Westcott R. C. Trostle, *Long-Term Prospects for Agriculture Reflect Growing Demand for Food, Fiber, and Fuel.* Amber Waves, September 2012, www.ers.usda.gov/amber-waves • Economic Research Service/USDA.

determine the level of yields as a derivative of the intensification of production and development of new technologies. The modeling results indicate diminishing growth yields despite the growing prices of food. This indicates the need to increase investment in research and the search for more efficient technologies for agricultural production. The expected growth of food prices is associated with an increase in demand for food in India and livestock products in China. Similarly the policy on utilisation of agricultural products for energy purposes leads to the growth of world food prices. On the other hand, introduction of energy crops appears to be beneficial for the developed countries. In this case, however, the benefits of economic growth in developed countries will directly increase the scale of hunger in developing countries. Construction of the model allows to determine the quantities of basic food commodities in order to stabilize prices, and additional costs associated with a change in consumer behaviour on a global basis (an increase of meat consumption). The results show that a significant increase in the engagement of agriculture in the energy production is highly doubtful having in mind priority of food security in a global context.

In the study for the European Commission economic performance of farms undertaking the production of biomass for renewable energy purpose was investigated and their effects on the economy of rural areas[12]. Surveys carried out among European farms have shown that Polish farms are characterised by relative highest income effects as a result of engagement in the production of biomass. Similarly, the development of this type of production resulted in an increase in the use of labor resources in agriculture. The study pointed to differences in the level of investment cost for this type of production between regions, mainly due to the differences in the technologies. The majority of respondents pointed to the greater importance of guaranteeing the purchase of biomass and raw materials for renewable energy at preferential rates than subsidies to investment. Engagement of farm resources in energy production is seen as an additional, stable source of income in case of preferential rates and long-term purchase contracts. Among the main negative effects of the development of this type of production study indicated the possibility of conversion of permanent grassland for dedicated crops for biogas production. The analyzes carried out showed that in 2020 the production of energy from agricultural waste should be

[12] *Impacts of renewable energy on European farmers creating benefits for farmers and society,* Edycja: Bas Pedroli i Hans Langeveld, AGRI-2010-EVAL-03, Final Report, 2011.

closer to the size of the energy produced on the basis of a dedicated plant species. The report pointed to the relatively lowest effective reduction of greenhouse gas emissions through renewable energy production based on biomass as compared to traditional agricultural crops. At the same time the report stressed that the plant dedicated to the production of biomass can have a positive effect on the growth of soil organic matter content and lower demand for nitrogen fertilizers. The simulations showed that in the case of maximizing the acreage dedicated to the production of biomass through increase of prices in the study area Warmia and Mazury, reduction of the production of cereals, such as barley and rye is expected and an increase of use of set-aside land and grassland for the production of biomass. On the other hand, increase of prices and production of rapeseed will gradually displace production of plants dedicated to the production of biomass. This mechanism indicates a high risk of undertaking biomass crop production. These crops due to the long-term investment nature decrease ability of farms to quickly adapt the structure of production to changing market conditions. In this sense, the long-term productivity of the farms in the production of biomass depends on the stability of the markets of energy plants and agricultural markets for traditional crops that can be used for biofuel production.

Dilemmas related to programming agricultural resources use for the production of renewable energy are of dynamic character. In the recent discourse devoted to the issue of development and interaction of agricultural production for energy and food three main phases can be distinguished: the consolidation and modification of the discourse and finally discontinuity[13]. At the stage of consolidation the development of agricultural production for energy purposes was treated as an integral part of development of agriculture. Such an approach was justified by expected positive influence of biomass production on farm development and on strengthening of the labour market and entrepreneurship in rural areas. Since these expected results were consistent with the objectives of agricultural and rural areas development policy agricultural production for energy purposes was integrated with agricultural policy. At this stage, the programming policy of renewable energy production based on agricultural resources emphasized its positive impact on rural employment and income, allevi-

[13] Kuchler M., Linner, B.-O., *Challenging the food vs. fuel dilemma: Genealogical analysis of the biofuel discourse pursued by international organizations*, Food Policy, nr 37, 2012, s. 581-588.

ation of poverty, and contribution to revitalization of agricultural sectors despite falling prices of agricultural products. In the light of the increased possibilities of agricultural production use productivity growth was expected. The expansion of agricultural production was particularly relevant in areas that have been withdrawn from agricultural production as it happened in Western Europe at the end of the twentieth century. The new market demand conditions were expected to increase the cost-effectiveness of a traditional agricultural production and on the other hand pointed to a lower input requirement for energy production. Simultaneously increase of investment in agriculture was expected that would result in growth of agricultural production for food purposes supporting strengthening food security. Consolidation of energy production with production of food meant that the final decisions about the use of agricultural production, regardless of its original purpose was subject to the rules of the market. In the study phase of policy modification is directly linked to the growing awareness of the limits of increasing agricultural production, mainly because of deteriorating natural resources. Simultaneously use of traditional agricultural production for energy purposes in terms of falling prices of fossil fuels has proven to be economically unjustified. Under such conditions it has become necessary to modify perception of energy production and in particular search for new more productive technology for agriculture. Among the considered directions of technological development the potential of genetically modified plants was emphasized related to their more efficient fertilizer use and lower requirements for pesticides. At the same time the need for specialization and increase the scale of production for energy purposes was pointed out. However, concentration of production was followed by undesirable concentration of its positive effects, especially in terms of agricultural land ownership and income. In this light, it was necessary to strengthen the position of small farms in the chain of production of raw materials for energy purposes. The increase of the use of agricultural raw materials for energy purposes in the face of growing food commodity prices motivated search for solutions neutral for food security. At this discourse phase, the positive impact of the development of energy based on agriculture of production was linked with long period perspectives. The negative correlation of bioenergy production and food security was recognised as of temporary character while due to the lag in reaction of investors to the high prices of agriculture products and to delay in the development of new technologies. At this phase the first and the second generation of biomass technology were defined. While the first generation biomass was linked with raw material based on the food and the second generation was based on plants dedicated to the production of biomass for energy purposes. This distinction became basis of differentiation of energy policy based on food commodities directly affect food prices and policies to encourage the production based on plants dedicated for use for energy purposes. In the case of second generation technology greater possibility of dedicated crops to growth on areas not suitable for food production was underlined. The current phase should be considered temporary because of the strong position of the first generation technology and developing stage of the second generation technologies.

Restrictions on energy production based on plants used for food production would lead to a loss of investor confidence and withdrawal of capital required to implement the second-generation technology. The implementation of the solutions that are not directly compete with food production carries a high level of risk arising from the strong fluctuations of the conventional energy sources prices. In the extreme case low fossil fuel prices and low profitability of renewable energy production can lead to the collapse of the entire sector what make it unsustainable.

1.2. Agricultural production for energy, natural resources and food security – national level

The impact of the production of biomass for energy purposes on level of the sustainability of agriculture in the environmental sphere is considered to be a complex issue. Therefore related studies based on multi-criteria analysis take into account different indicators. The research conducted by A. Faber distinguishes five areas of interactions between energy crops and environment: climate change, soil and water resource management, biodiversity and landscape[14]. According to the research results general opinion about the positive effects of biomass production for energy purpose on climate is controversial and can be justified in case of the second generation biofuel production. Studies in area of climate changes related to biofuels production based on crop products indicate a worse impact on the environment as compared with the gasoline. Analysis of the full chain of production and use of biofuels and energy based on crude oil showed that the biofuels produced on the basis of the first-generation technology emit more greenhouse gases than gasoline. In this light, the productivity of agricultural resources used for production of biomass for energy purposes depends on the further development of biomass conversion technologies.

Among most important parameters used for assessment of the production of energy crops impact on soil is the level of carbon sequestration. Conversion of the carbon assimilated by plants in humus is considered critical for improvement of soil productivity. Author of the study underlines that positive impact energy crops on carbon balance depends on climatic conditions, soil granulometry and original content of humus in the soil. Similarly, perennial energy crops have a better management of nitrogen compared to traditional crops. That is manifested by reduced nitrogen leaching and the use of permanent crops for phytoremediation of contaminated water and soil. Among the perennial energy crops species characterized by lower evapotranspiration per unit of produced raw material for the production of renewable energy are of special interest. Namely they can be considered to be relatively more efficient in terms of water management – that is critical from the sustainability of water resource utilisation. However, despite the better water management of perennial energy crops

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[14] Faber A., Przyrodnicze skutki uprawy roślin energetycznych. Studia i Raporty IUNG-PIB, nr 11, Puławy 2008, p. 43-52.

this production demands greater water amounts compared to conventional agricultural crops while providing a larger amount of biomass. These crops thus contribute to a reduction in groundwater reserves suggesting a negative impact on the water balance. It is critical for Poland characterized by negative climatic water balance. On the other side the cultivation of energy crops can be considered beneficial for biodiversity. Significant increase in the number of species was observed as a result of the replacement of traditional agricultural crops with energy one. Definitely a negative impact linked with perennial energy crops refers to the values of the agricultural landscape. This is due to the need for integration of significant areas of land under monoculture energy crops to benefit form economy of scale resulting in reduction of the open nature of the agricultural landscape. Concluding the results of the research, A. Faber emphasizes on the one hand an advantage of perennial energy crops over traditional agricultural crops in terms of energy and carbon balance, their impact on soil and biodiversity, however stressing need of adjustment of this production to local environment conditions and appropriate agricultural technology utilisation. On the other hand, energy crops pose a greater threat to the water and the landscape resources compared to traditional crops. On this basis, it can be concluded that the perennial energy plantations can have relative, i.e. compared to the traditional cultivation of cereals, positive impact on the environmental sustainability of farms. In particular, through the sequestration of carbon dioxide such crops help to reduce pressure on global warming. Therefore, this production contributes to natural resources management on the global economy level. Positive impact on the restoration and conservation of soil translates directly into productivity. In this sense, energy plantations have a positive impact on the economic sphere. The high demand for water of energy crops results in a deterioration of Polish agricultural sustainability in the environmental sphere. Only farms in regions with a surplus of water resources could be involved in the production of biomass for energy purpose to minimize the negative impact of this production on water resource management. The effectiveness of energy crops production is determined besides accessibility to water by quality of the soil, temperature distribution and the length of the growing season[15]. At the same time, due to the high cost of establishment of plantations and long term economic performance of

[15] Jadczyszyn J., Faber A., Zaliwski A., *Wyznaczanie obszarów potencjalnie przydatnych do uprawy wierzby i ślazowca pensylwańskiego na cele energetyczne w Polsce,* Studia i Raporty IUNG-PIB Puławy 2008, s. 54-65.

investment it is critical to optimize plant species to local conditions and to minimize the cost of cultivation.

Table 1. Forecast changes in acreage and crops by 2020

Direction of land use	Change in demand for biomass compared to 2006		% change in the area compared to 2006			% change in price compared to 2006		
	thous. tonnes	%	1	2	3	1	2	3
Wheat	798	11	-30	-25	-2	117	130	326
Oats and mix	483	11	-14	-14	-1	120	151	223
Other cereals	1136	11	-22	-20	-8	85	102	50
Rape	2820	171	55	165	130	-23	-14	-50
Sugar beet	0	0	6	5	-15	54	56	65
Potato	0	0	-11	-12	-29	74	76	59
Fodder	0	0	-41	-43	-53	59	63	81
Meadows and pastures	0	0	-21	-26	45	165	180	185
Energy crops	6600	2868	-14	5735	5726	113	88	588
Set-aside and fallow land	-	-	-45	-51	-67	-	-	-

Source: Stuczyński T., i in. Prognoza wykorzystania przestrzeni rolniczej dla produkcji roślin na cele energetyczne, Studia i Raporty IUNG - PIB, z. 11, Puławy 2008, p. 37.

In the study undertaken by a team of T. Stuczyński the potential expansion of area for biomass production was investigated taking into account the competitive directions of agriculture productions, as well as the ongoing process of transformation of agricultural land for non-agricultural purposes[16]. In this research utilised economic area is defined as a resource that is optimally utilised in regard to economic efficiency and regulations. The last ones are mainly linked with the protection of the environment and spatial planning policy. In the study the processes governing the size of distribution of resources in the various categories of land use are a subject of Dynamic System Modelling. In

[16] Stuczyński T., i in., *Prognoza wykorzystania przestrzeni rolniczej dla produkcji roślin na cele energetyczne*, Studia i Raporty IUNG - PIB, z. 11, Puławy 2008, s. 25-42.

this model relation between measurable factors describes the possible land utilization. The use of the DSM allowed for determination of trends in the structure of Polish agricultural land use till year 2020, assuming fulfillment of the strategic share of agriculture in biofuel production. In the study the cost of production of certain crops is used to optimize their percentage share in the land use.

The results pointed to the increasing competition for agricultural land between agriculture production for food and energy purpose under policy scenarios aiming at increase of the share of renewable energy in the total energy use. Depending on the scenario in question it is expected that growing demand for food and the demand for biomass for energy will result in prices increase of basic crops, especially cereals. Authors of the study underline preliminary character of estimated impact of policies on the structure of the biofuel crops in Poland. The early dynamic stage of development of market for energy crops resulted in problems with calibration of the model that is based on historical data. Similarly, the model does not take into account the increasing volatility in the level of agricultural production due to climate change, and refers to the area of the country. Therefore it omits from the one hand, factors affecting the global supply of agriculture production and on the other hand regional agricultural production conditions namely environmental and socio-economic nature. Among the benefits of biomass production expansion authors point out increase of cultivation of set-aside and fallow land. Therefore, this direction of production prevents the loss of land from agriculture. At the same time, despite the increase of competitiveness for the agricultural area, we cannot expect a significant decline of area of crops for food, due to the expected increase in the price of these products.

Results of the research conducted with the use of Geographic Information System – GIS confirm that relatively small area of Polish land can be used for the production of biomass for energy purposes[17]. In the study variability of natural conditions for agricultural production as well as soil complexes of lower suitability for the production of food were taken into account to determine potential area for growing energy crops. Preliminary determined area was reduced

[17] Pudełko R., Faber A. *Dobór roślin energetycznych dostosowanych do uprawy w równych regionach kraju.* [w:] Bocian P., Golec T, Rakowski J. (red.) *Nowoczesne technologie pozyskania i energetycznego wykorzystania biomasy*. Instytut Energetyki, Warsaw 2010, s. 50-68.

by excluding areas unused by agriculture, mountainous, characterized by less than 550 mm rainfall, with ground water resources that are not available to plants as well as environmentally protected areas. Inclusion of economic and agricultural production conditions criteria resulted in reduction of the potential area of 1.1 million hectares to ¼ to be used for energy crops purposes. Authors of the study stressed that determined area for energy crops is significantly lower than indicated by other international research centers. Depending on the research center it was indicated that it is possible to use from 1 million to up to 8.5 million hectares of agricultural land in Poland for energy crops over the next 10-20 years. It must be stressed that in presented estimates the principle of the primacy of food security over energy production was maintained. This means that the land earmarked for the production of biomass for energy purposes does not cause reduction in food production required to meet the food needs of the world. The key parameters in the listed models were projected increase of demand for food and agricultural productivity growth in the production of food and raw materials for animal feed. Therefore the difference between the results indicates sensitivity to technology development factor.

Among the studies devoted to cost-effectiveness of the production of biomass for energy purposes estimations of long term competitiveness are of special interest. In the research conducted by E. Krasuska method of estimation of the price of biomass for energy purpose that ensures long-term viability and competitiveness of the energy crops was proposed[18]. Among the crop for energy products included in the analysis were willow, miskantus, virginia mallow and willow grown in the Eko-Salix on permanent grassland. In the research costs and effects of crop production designated for energy purposes were estimated for different production conditions. These included expected yield depending on soil complexes with the exception of protected land and land with negative water balance. With the use of FADN data main types of farms were recognised: specializing in field crops, milk production, animal production, mixed production and pig production. The study included the need to increase the size of the biomass price premium to offset the risk of taking this type of production. This need for such a premium was justified as compensative for increased risk of

[18] Krasuska E., *Metoda szacowania cen biomasy dla energetyki z uwzględnieniem premii za ryzyko*, IUNG-PIB, Puławy 2011.

undertaking the production of biomass as an alternative direction for agricultural production for food. The increase in risk was associated with the need to bear high investment costs of establishing plantations and uncertainty as to the level of profitability of this type of production in conditions of high volatility of the market. Namely the difficulty of estimating the level of profitability from the market perspective is associated with the uncertainty of production costs and biomass price stability. From the other side the high risk from production perspective corresponds to the yield uncertainty and indirectly to effectiveness of the investments (purchase of specialized equipment) and the acquisition of new skills. As a result, payments to support the establishment of plantations and the need to ensure that sales of raw materials will base on long-term contracts are essential in the expanding of this type of production. Despite postulated support programs and national programs of expansion of removable energy production in the study production of biomass for energy purposes is considered as supplementary for the production of food. Therefore, only marginal or fallow agricultural land is taken into account as possible area for biomass production. This assumption suggests that, in practice, the production of biomass for energy purposes is not the direction that would become the basis for the generation of income of a larger group of farms in Poland. As a result, assuming a stabilization of the market environment and the support of agricultural production it can be expected that this trend will not affect significantly the level of food production in the medium term perspective.

In the study with the use of Polish FADN data representing economic performance of the farms the level of the risk premium for biomass production was estimated. This was done in relation to agricultural production, such as crops, milk and pig production as well as rearing pigs. Based on the real data standard gross margins for the agricultural and biomass production were calculated taking into account the risk premium. This allowed for identification of the relationship between the type of farm production and its potential willingness to undertake the production of biomass for energy purpose. The results of the study indicated that the farm would maintain profitability while implementing production of biomass.

Table 2. The level of risk premium and final price for willow biomass for energy purposes in relation to conventional lines of agricultural production

Studium	Type of production	Risk premium zł GJ^{-1}	Final price zł GJ^{-1}	Share of premium in the final price
Clancy et al. 2008b	Winter wheat	13.64	42.44	0.32
	Barley	-1.28	27.52	-0.05
	Milk production	61.76	74.98	0.82
	Raising sheep	11.00	39.80	0.28
	Raising calves	8.08	36.88	0.22
Own results	Crop production	8.75	22.13	0.40
	Mixed production	8.45	19.35	0.44
	Cattle production	11.50	26.07	0.44
	Raising pigs	1.15	24.49	0.05

Source: Krasuska E., Metoda szacowania cen biomasy dla energetyki z uwzględnieniem premii za ryzyko, IUNG-PIB, Puławy 2011, table 24.

On the other hand, the implementation of biomass type of production requires the highest prices (and premiums) in case of farms specializing in pig production. That is a result of highest standard gross margin in this type of agricultural holdings. It must be underlined that in the study standard gross margins were calculated per hectare of agricultural land, which determined the better position of farms specializing in the production types closely associated with the area of agricultural land. The study showed that the average cost of biomass production in all types of farms exceeds the average price of biomass in the domestic market. This includes effects of regulations on biomass prices related with obligatory use of green sources energy by energy sector. Only in selected municipalities with a predominance of farms specialising in crop production or mixed-crop production and with the relatively larger area, farms are likely to take biomass type of production in the event of a price close to the upper limit of prices paid by the energy sector.

The study showed that in the current market conditions and available technologies expansion of the production of biomass depends on the level of support to cover related risks. Alternatively setting up the lower limit of prices enough to cover the average annual cost of biomass production is necessary. Simultaneously the study indicated that the relatively lower use of fertilizers and pesticides in the production of biomass crops in comparison with food crops reduce extensively the risk associated with the volatility of the prices of means of production[19].

Research conducted under the leadership of E. Majewski confirmed strong influence of different policies on the involvement of Polish farms in production of biomass for energy purpose[20]. In the research linear optimisation model was used to indicate changes in the structure of farms, depending on the level of support for energy production. In order to characterize the Polish agriculture parameters derived from the farms engaged in agricultural accounting FADN system were used. The study determined 210 different groups of farms depending on the type of production, the size of land used, the intensity of production and soil quality[21]. Parameters used for market description in the optimisation model were derived with the use of partial equilibrium model AGMEMOD. In this case prices for basic agricultural products calculated by the model accounted exogenous variables reflecting various agricultural policies and the impact of world market on domestic prices. Namely in this model domestic prices are a function of: world prices, policy instruments (agriculture, trade, energy) and domestic demand-supply relationship on main markets. Price changes affect the allocation of land resources for particular directions of production and the interactions between plant and animal production are represented by the disposal of crop production for fodder use (and crop production prices). The study compared the changes in the structure of agricultural production for the baseline scenario – assuming no production of biofuel and agricultural policies with alternative scenarios which assume growth of the agriculture production for renewable energy purpose, in particular the increase in demand for cereals and oilseed rape for biofuel production. The study took into account the moderate increase of productivity as a result of technological progress. The simulation indicated that the increase in demand for biofuels together with enforced regulations or subsidies will mainly increase rapeseed prices (depending on the scenario by 129 to 138%) and wheat (by about 124 to 133%). The projected increases in plant products' prices will increase prices of fodder. Consequently, it is also expected that the prices of animal products will increase,

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[19] Ibidem, p. 77.

[20] Majewski E., Wąs A., Hamulczuk M., *Farm level modeling of bio-fuel and bio-power policy scenarios for Polish agriculture*, International Farm Management Association, Bloomington (Ill.), USA, 19-24 July 2009.

[21] Detailed description of the model is included in the Report PW no. 148.

but relatively moderately, while the costs of animal production will be higher. Results of land use modelling indicated that compared with the baseline scenario reduction in wheat area and root crops is expected together with moderate increase of area of crops for fuel production. The changes in the structure of production were explained with the preference for crop production characterized by a lower intensity in response to the strong increase in prices of means of production, especially mineral fertilizers. On the other hand the moderate increase in oilseed production is directly correlated with the increase in demand for these crops for energy purposes. Demonstrated relatively stable forage production reflects insignificant impact on demand for livestock products in the conditions of increased production for energy purposes. The calculations under different scenarios regimes highlighted role of policies in increase demand for agricultural raw materials for biofuel production. Namely strong increase in the production of wheat and crops dedicated for energy purposes in the structure of production at the expense of other crops is a response to policies subsidising renewable energy production. In this scenario expected sharp increase of wheat prices stimulates intensification of production.

The policy aimed at development of agricultural production for biofuels is expected to have strong impact on small and medium sized farms. On the other hand the weak interest in this direction of production was observed among the largest farms. This phenomenon is explained with a high demand for labour inputs in the production designated for biofuels. While the small farms are characterised with excessive labour forces they are suitable for this kind of production. The study indicated that surpluses of farm labour next to polices aiming at stimulation agriculture production for energy purpose are key factors of undertaking this production. Strong growth in demand for raw materials for the production of biofuels will push out less intensive crop production by energy crops and on the other hand increase the area of intensive crops for food. This relationship proves lack of neutrality of policy aiming at increase of biofuels production on the level of traditional agriculture production in the face of the expected growth in global demand for food.

Table 3. The share of major crops in the structure of agricultural production (in %) by different farm size

Crop production	BASE 2006	BLINE 2013	BIOF 2013	BIOP 2013	BASE 2006	BLINE 2013	BIOF 2013	BIOP 2013
	up to 10 hectares				10-30 hectares			
Cereals	84.9	88.7	87.1	77.5	69.8	68.9	68.2	60.2
Oilseeds	1.9	2.3	2.9	2.4	7.5	13.6	13.6	13.6
Sugar beet	9.1	4.8	5.7	6.0	10.7	4.2	5.1	5.0
Biomass crops	-	-	-	9.95	-	-	-	9.6
	30-100 hectares				more than 100 hectares			
Cereals	63.4	69.5	69.2	61.5	70.6	75.6	75.1	74.9
Oilseeds	10.5	10.5	10.5	10.5	18.4	18.3	18.3	18.3
Sugar beet	8.8	2.9	4.2	4.4	7.3	3.5	4.5	4.5
Biomass crops	-	-	-	8.6	-	-	-	0.2

Source: Majewski E., Wąs A., Hamulczuk M., Farm level modelling of bio-fuel and bio-power policy scenarios for Polish agriculture, International Farm Management Association, Bloomington (Ill.), USA, 19-24 July 2009.

Assessment of the productivity of the agricultural sector in terms of production of food and raw material for the energy purposes has a complex character. This complexity is manifested by competitive nature of these two types of production. From the perspective of sustainability of agricultural production it must be outlined that the competition in the case of technology that uses traditional crop products for energy production has a direct character while technologies based on crops dedicated for biomass production indirectly compete for food production resources. Agriculture sector as a representation of combined decision of individual farms optimally adjusts the profile of production to market conditions. Agricultural producers make decisions on the volume of production, both in the production of raw materials as well as the production of biomass for energy purposes regarding their farm capacity and external factors. Among the last ones growing demand for food, environmental constraints, the need for renewable energy sources with the availability of effective technologies are the main determinants of agriculture productivity.

2. Technological aspects of biomass production for energy purpose

The energy sector is increasingly cooperating with agriculture, recognizing its potential for production of renewable raw materials for the production of energy. In the light of development of renewable energy sources and preparation of national energy regulations it is expected that agriculture will be able to produce energy to meet its own needs as well as for other sectors of the economy. The support mechanisms designed for renewable energy production affect differently specific technologies and have a different impact on scale of renewable energy production. So far, the current national system of support has resulted in the development of large-scale co-burning of biomass in power plants. In this system the role of the agricultural sector consists mainly in supply of biomass and production of raw materials for the production of biofuels. Farmers benefit as well from the fees for the lease of agricultural land that is used for wind turbines.

The observed trend in the European Union of promotion of disperse systems of energy, consisting of small installations (micro installations) is in contrast with centralized Polish model. The disperse system is more advantageous for the agricultural sector and underlines model of production for own consumption with the surplus energy provided to general energy network. Similarly the model of "green heat" which in a simple and energy-efficient way utilizes own produced biomass for heating purposes is underdeveloped as compared to its potential.

In this chapter a general classification of renewable energy technologies based on biomass is presented. Technologies of renewable energy production refer to processes of primary biomass conversion into electricity, heat, biofuels and biogas for consumers. The main biomass conversion types discussed here are thermochemical conversion, physicochemical and biological. Next the issues of energy production from biomass based on different raw materials are presented as well as based on renewable energy technologies not linked with production for food and using natural sources of energy, such as wind and solar.

Finally the logistic issues as well as current mechanism of support of electricity production from renewable energy sources are to point out possible sector development directions.

2.1. Basic classification of conversion of biomass into usable energy

The agricultural sector can provide biomass based on crop products and of production waste. In the first case biomass can be based on the food crops where the raw materials are alternatively processed for energy purposes and cultivation of plants designated solely for processing into energy. The largest amount of waste biomass is connected with straw and animal husbandry. Each of these types of biomass can be converted into electricity, heat, biofuel or biogas with the use of specific technologies of conversion. These are namely thermochemical, physicochemical and biological conversions[22].

During the thermochemical conversion biomass is subject to chemical breakdown under high temperature. There are four processes: combustion, gasification, pyrolysis, and roasting. These processes differ mainly due to the temperature ranges, heating rate, and the amount of oxygen during the reaction. In the case of biomass of agricultural origin most commonly combustion and thermal energy generation is used.

Physicochemical conversion is used for the production of liquid fuels (biodiesel or vegetable oils). It consists in the extraction of oil from oil seeds (e.g. rapeseed, soya), which can then be subjected to the process of transesterification. In case of Poland this process is commonly used for rapeseeds conversion.

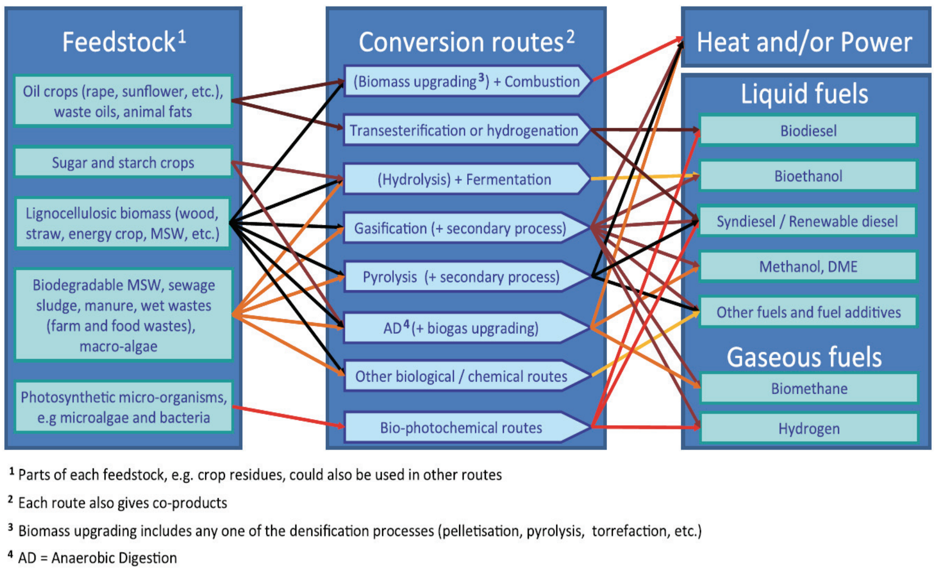
In the process of biological conversion living microorganisms (mainly bacteria) decompose the raw material and are used for the production of liquid and gaseous fuels. There are many technologies for such conversion and use the processes of:

- fermentation of sugar (e.g. sugar beet, sugar cane), starch (from cereals, maize) and lignocellulose raw materials (such as grass, wood)
- anaerobic digestion (mainly of wet raw materials)
- biophotochemical reactions (e.g. hydrogen production using algae), which require light.

[22] Compare with Bioenergy – a sustainable and reliable energy source. A review of status and prospects IEA-Bioenergy, 2009 page 27.

Figure 3 shows various conversion processes corresponding to the diversity of raw materials. On one hand the conversion process is determined by type of biomass, and on the other hand by the demand for the final product. Selection of conversion process determines the efficiency of energy production from biomass taking into account local conditions of supply of raw material and energy demand.

Figure 3. Biomass conversion processes



Source: Base on IEA-Bioenergy, 2009.

A key factor that determines the directions of biomass use relates to the costs of its production as well as the support system. In reality the key factors are the state energy policy and the detailed arrangements followed by operating costs of the conversion technology and cost of raw material. Economic calculation that takes into account these factors determines the individual business decisions concerning the selection of technology and the size of the installation.

The current regime of support (system of green certificates) biomass is mainly used as fuel for combustion (conversion thermochemical) and electricity production (for cogeneration also the heat is generated), for the production of heat and for biofuel production (conversion physiochemical) and for biogas (biological processes). The different types of conversion consists of specific processes, which will be described as a solutions used in Poland.

Pre-processing of biomass

Pre-processing of biomass is used to increase the energy density, uniform physical properties and size, which is important due to the technological requirements of power plants (biological stability) and facilitates logistics operations. After processing, the biomass supply is also easier to settle in trade, e.g. based on its calorific value (which is affected by relative humidity). In case of agriculture origin raw material straw and energy crops are processed into form of briquettes and pellets.

Briquettes can be produced from wood chips (sawdust, shavings, chips), straw, hay[23]. Briquetting process is performed by mechanical or hydraulic presses. The raw material is dried and ground so as to obtain a homogeneous fraction for final briquetting. Ready briquette is conditioned and packed.

According to the current standards in some countries briquettes should be geometric (cuboid, cylinder, etc.). The density should be between 1 to 1.4 tonne/m^3; relative humidity below 12% and calorific value in the range of 17.5-19.5 GJ/t, content of ash less than 1.5%. Briquette production is simpler and cheaper than the production of pellets. Pellets are produced from waste wood and agricultural raw materials, in the form of granules. Production of pellets is similar to the production of briquettes. Raw material in the typical production process is shredded (finely ground), screened, dried. Then it is mixed and subject to pelletisation, which involves high-pressure pressing on the cylindrical press. The obtained pellets are conditioned and packaged. Cylindrical pellets have a diameter of 6-25 mm and a length up to 5 cm. The energy value is equal to 16.5-17.5 MJ/kg, the humidity is 7-12%, ash content below 1%, bulk density ca. 650 kg/m^3. Selection of the raw materials in pellet

[23] In the production of briquettes of wood it is not necessary to add additional binding substances – contained in the wood resin acts as a binder. In the production of briquettes from other materials, such as straw or hay, it is necessary to use additives.

production is more important than is the case in the production of briquettes and arises from the need to achieve better effects in compression, smoothness and durability. Pellets do not require a large area of storage, they can be supplied without packaging – by trucks, rail or by ships. They can be stored in sheds, silos, tanks, internal and external. The raw material must be stored in dry conditions, with ventilation. Due to internal logistics it is important to ensure availability for quick unloading.

According to the analysis of selected technologies of production of pellets and briquettes from energy willow, the production costs for 1 tonne of pellets amounted to PLN 321.4, for briquettes it was PLN 219.4. The raw material came from own plantations and its cost was respectively: 10.4 PLN/t (pellets) and 4.8 PLN/t (briquettes)[24]. The increase in functionality of the final product substantially affects the cost of production. On this basis, it can be argued that the pelletisation is more competitive in small scale production of energy in comparison with briquettes.

Thermochemical conversion of biomass

The most common decomposition of biomass are combustion, gasification and pyrolysis. Biomass is subject of oxidation reaction during which the heat is generated. In the context of biomass of agriculture origin, it is important to maintain stable humidity and chemical composition of the raw material, which determine the possibilities of specific technical solutions utilisation. Moisture of biomass apart from affecting the calorific value, makes storage and sanitary problems. Therefore it is advisable to lower the level of humidity and unify its properties. The chemical composition of biomass affects the combustion process, the emissivity and the amount of residue ash. Particular problems associated with using straw are related with the high chlorine content.

The burning of biomass for heating is a simple, widely applied method of using renewable resources of energy. Technology solutions depend primarily on the size of the installation. Domestic installations (furnaces and boilers) are solutions commonly used in individual households. Modern boilers for pellets

[24] The cost of raw material is low, the pellet price is higher as the addition of 10% by weight of rapeseed cakes for improving the properties.

achieve efficiency of 90%, however, mostly there are installations of lower capacities, about 60-70%.

Heating systems consist of installations, which produce heat and provide it to customers through a heating network. There are numerous technical solutions on the market, the choice of equipment intended for biomass combustion is wide. Heating systems use feeding furnaces and furnaces with mechanical grates. The heat is also generated in cogeneration units. Power installations generating electricity and heat in combination have more power and use both fluid and pulverised-fuel boilers.

Large installations use furnaces with solid beds and fluid beds, which are flexible in terms of the diversification of fuels and the possibility of using cheaper raw materials, also waste raw material. The furnaces with fluid boilers are currently the most commonly used option.

In plants with a capacity above 5 MW fluidized beds are used that are flexible in terms of the possibility of using different fuels and mixtures, including the use of waste materials. Fluidised bed furnaces with boilers are currently the most widely used solution for combustion and co-combustion biomass and coal.

Industrial systems are installations with power rating from 0.5 to 20 MWt. The heat produced in such installations is generally used for own needs of industrial plants. In many cases the plants use waste material from the site, for example, waste wood, to produce heat and process steam. The heat from the combustion of biomass in boilers can be used for the production of electricity in a steam turbine or piston engine. The efficiency of electricity generation in the steam cycle is lower than in other technologies, e.g. using the gasification process. The solution is used often in Poland because of the low cost and simplicity of implementation. The cost of generating electricity from biomass is strongly dependent on the supply of raw material, its fragmentation and can significantly increase due to transportation distance. Revenues from biomass combustion depend on the support mechanism and are the primary reason for conducting this type of activity.

Table 4. Operating costs of generating electricity by technology in Europe in 2008

Technology	Net efficiency	Capital expenditure	Operating costs without fuel	CO_2 emissions
	%	EUR/kW	EUR/kWh	kg/kWh
Pulverized Coal Combustion	46-47	1380-1880	0.041-0.050	0.73-0.88
Circulating Fluid Bed Combustion	41-43	2040-2490	0.040-0.3048	0.68-0.70
Conventional thermal power plant - coal	34-37	2810-3430	0.023-0.028	0.95-1.16
Conventional thermal power plant - lignite	32-34	2550-3110	0.037-0.045	0.99-1.21
Integrated Coal Gasification Combined Cycle	45-46	2320-2830	0.093-0.113	0.70-0.75
Combined Cycle Gas Turbines	60-61	690-840	0.046-0.056	0.34-0.40
Gas fired Conventional Thermal Power Plant	50-51	430-530	0.049-0.059	0.46-0.56
Gas fired Gas Turbine	40-42	560-690	0.131-0.161	0.46-0.58
Oil Conventional Thermal Power Plant	32-33	390-470	0.039-0.052	0.74-0.90
Oil fired Gas Turbines	35-36	405-475	0.027-0.046	0.65-0.75
Internal Combustion Engine	41-43	630-820	0.022-0.024	0.71-0.86

Source: Base on Tzimas, Moss & Ntagia, 2011.

There is a direct co-combustion, where biomass is mixed with fuel base (usually coal) before mixing and feeding the mixture to the boiler, or independent preparation and application of biomass. Indirect co-combustion uses Dutch oven, from where the exhaust heat goes to the combustion chamber of the boiler, or initial gasification of biomass – in this case combustible gas is introduced to the chamber. The growing demand for biomass confirms completed, executed and planned investments in the energy sector professional in this field[25].

[25] Recently completed and developing investments are: Połaniec Power Plant, GDF Suez: biomass block 190 MM, full power is to be achieved in 2012, Szczecin Power Plant, PGE: biomass boiler 64.5 MWel, completion in 2012, Elbląg Combined Heat And Power Plant, Energa Kogeneracja Elbląg: biomass block, 20 MWel, launch in 2013, Dalkia Polska, investments in Łódź and Poznań: total power of 67 MW, completion in 2011, Tychy Combined Heat And Power Plant, Tauron: adapting the existing boiler 40 MW to biomass combustion, scheduled launch at the end of 2012, Tychy Combined Heat And Power Plant, Tauron: 55 MW cogeneration, by the end of 2016 and Jaworzno Power Plant, Tauron: 50 MW biomass boiler, planned completion by the end of 2012.

Rural areas are characterized by the abundance of biomass that could easily be utilised on the spot, which reduces transport costs and creates the added value of the farm and the region. The significant role of technology of co-centralized biomass power stations increases price of biomass resulting in high imports, and have a negative impact on development and dissemination of small scale technologies. The issue of inefficient use of biomass are described in detail in the report "The unsustainable use of renewable energy resources in Poland and pathology in the system of its support"[26]. From the point of view of rural areas and energy management, the current system of support is ineffective because locks the development of small-scale technology. The agricultural sector can successfully deliver biomass in the form of pellets and briquettes from straw and energy crops for the production of heat and electricity. It is argued that biomass can be prepared and processed on side and used for farming purposes in line with required heating technology regimes and sanitary requirements.

Thermochemical process involves performing gassing of fuel in solid or liquid fuel gas by thermal decomposition in the cycle alternating with the oxygen, carbon dioxide and water vapour. In this process the fuel is of high carbon content, and the process is carried out under controlled conditions, in the reactor. The product of the process is a synthesis gas which comprises primarily of carbon monoxide, hydrogen and methane. There are two advantages of gasification compared to the conventional combustion of the fuel. First gasification is highly versatile with regard to the fuel type and any type of biomass can be very efficiently converted into a gaseous fuel. Secondly, fuel gas can be used directly to generate heat and electricity, and can also be used to enrich the synthesis gas for biofuel production[27].

In small plants (<10 MW) simple gasification systems are in use, generally with gas engines. For installations above 30 MW steam turbines are required. However such systems are just entering the domestic market and are

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[26] Wiśniewski G., Michałowska-Knap K., Arcipowska A., *O niezrównoważonym wykorzystaniu odnawialnych zasobów energii w Polsce i patologii w systemie wsparcia OZE. Propozycje zmian w podejściu do promocji OZE i kierunków wykorzystania biomasy*, Ekspertyza dla Ministerstwa Gospodarki, 2011.

[27] Compare with Bioenergy – a sustainable and reliable energy source. A review of status and prospects, IEA-Bioenergy, 2009, page. 32.

perceived as innovative solution[28]. Gasification of biomass in turn is a process commonly used in relatively small boilers. In this case, the burned wood under hypoxic conditions is gasified, and the resulting wood gas is combusted in the next chamber. The gasification process is also used for indirect co-burning of biomass. In this process fuel is subjected to pre-gasification in the Dutch type oven and then combustible gas is introduced into the combustion chamber. This method is used in the power industry due to adaptability of boilers for different fuels.

The pyrolysis process is thermochemical decomposition in a high temperature without access to oxygen. Depending on the temperature at which the reaction occurs low temperature (450-700°C), medium (700-900°C) and high-temperature pyrolysis (900-1100°C) are distinguished. The pyrolysis process may be used to pre-treatment of biomass, which, in liquid form, such as pyrolysis oil, can be processed into the second generation of biofuels. The benefit of indirect, costly process of pyrolysis is lower logistics cost. The pyrolysis process is considered as advanced technology of processing of raw material, and although the process is well understood and researched, this solution is not commonly used.

Concluding, it should be noted that the conversion processes are elements of technologies to convert biomass to produce heat and other form of energy. The biomass combustion processes using pre-gasification can be applied in small boiler for house heating systems, in cogeneration systems of a few MW capacity as well as in industrial energy installations. On the other hand the pyrolysis processes are developing and their wider use depends on technological progress.

Physicochemical conversion of biomass

Physicochemical conversion processes are used in production technologies of liquid biofuels. Transesterification is the process of conversion used in the production of esters through reaction of esters (other alcohols or other acids) with alcohols (alcoholysis), acids (acidolysis) or other esters and finally bio-

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[28] As an example Qenergy (Greenevo Laureate) offers complete cogeneration plant with a capacity of 1 MW biomass gasification.

diesel. In industrial practice, the process of transesterification is conducted at 60-70°C in the presence of an alkali catalyst. Differences in biodiesel production are the result of physical parameters of the process (pressure, temperature), the catalyst, and methods of treatment of esters and glycerol. Transesterification reaction catalysts can be acids, alkalis or biocatalysts (e.g. lipase). Recently the use of boric acid as a catalyst for this reaction is tested.

Hydrolysis is the reaction between water and the substance dissolved in it, which results in new chemical compounds. The processing of biomass uses enzymatic hydrolysis and chemical hydrolysis (acid, alkaline, ozonation, oxidation and other methods). The process of enzymatic hydrolysis supports the anaerobic decomposition of biomass using the enzymes. The chemical hydrolysis uses acids and alkalis in appropriately selected concentrations and process conditions. It also uses only water and the conditions of the reaction change. In each case, the hydrolysis partially destroys the structure of the raw material, to facilitate further technological processes, e.g. fermentation.

Hydrogenation consists in adding hydrogen molecule to molecule of organic compound containing unsaturated bonds. Industrial hydrogenation processes are carried out in the temperature from 25°C to 250°C. Hydrogenation processes are carried out in both the gas and liquid phase. Hydrogenation is used on a massive scale for the production of margarine, where liquid unsaturated vegetable fats are transformed at room temperature into saturated fats not having C-C double bonds in their hydrocarbon chains; this produces much greater amounts of trans fats (above 5%) than in animal fats, including butter (3-5%).

These processes are commonly used in industrial scale. Under the Law on components and liquid biofuels in 2006 allowed the farmers to produce biofuels for their own use. Namely the law was entered after introduction on the market technical solutions for production of esters.

Production of bioethanol and biogas with the use of biological processes

Fermentation is a biochemical process and in the context of biomass conversion, alcoholic and methane fermentation are applied. Alcoholic fermentation involves the breaking down of carbohydrates by enzymes produced by the yeast. Alcoholic fermentation is for cereals, beets, potatoes. A product of fermentation is alcohol and popular biofuels – bioethanol. Anaerobic fermentation is a biological process of decomposition of biodegradable substance by bacteria (anaerobic) in conditions of lack of oxygen. The process of methane fermentation is suitable for food processing wastes, biodegradable fraction of urban waste, sludge, animal faeces. The product of the process is the biogas, a mixture of gases, whose main components are methane and carbon dioxide.

During the process it is also important to maintain a constant, high temperature, suitable pH (> 6.8) and high humidity. Depending on the temperature of the process, we distinguish mesophilic fermentation (ca. 32-35°C) and thermophilic fermentation (ca. 55-57°C), appropriately for the type of bacteria.

The biogas can be used for energy purposes, or after additional processing can be forced into the natural gas network. The process of anaerobic fermentation is used in biogas plants. Independently, it takes place in landfills of waste and in wastewater treatment plants, where degassing systems and recovery of biogas systems are used accordingly; biogas is then used for energy purposes (usually to generate electricity and heat).

2.2. Production of energy from biomass based food raw materials

Crop production in Poland is an important branch of the agricultural sector. Production is dominated by cereals, roots, particularly potatoes (despite the annual decline of area under cultivation) and fruit and vegetables. Growing plants for non-food purposes is becoming increasingly important, including the cultivation of energy crops. Although the sector of energy crops in Poland is at an early stage of development, it enjoys a growing interest of farmers as an alternative source of income. Production of cereals is primarily the specialization of central regions in Poland, North-East and North-West. The cultivation of potatoes is the domain of voivodeships of the central belt and the South-East. Oilseeds are grown mainly in North-Western Poland, industrial plants, e.g. tobacco – mostly in voivodeships: Lubelskie, Podkarpackie, Świętokrzyskie, Kujawsko-Pomorskie and Małopolskie. Thanks to favourable soil, climate and economic conditions, Poland is currently the largest producer of potatoes and one of the four largest producers of rapeseed on the European market. At the same time, sugar beet has a substantial share in the crop production and is traditionally associated with Polish agriculture. The main areas of production of this plant are voivodeships Wielkopolskie, Kujawsko-Pomorskie and Lubelskie. Production of fruit and vegetables, because of the soil conditions and climate, is located primarily in the Central and South-East regions. Cereal production at the beginning of XXI century was characterised by high volatility due to climate conditions. Compared with the previous decade, there had been a moderate upward trend of cereals production and the share of cereals in global crop production reached about 40%[29].

According to the National Action Plan (NAP) the basic raw materials for first generation biofuels are: for bioethanol – cereals, molasses, biodegradable waste[30]. For biodiesel these are rapeseed oil and other vegetable oils, including imported oils. Biodiesel production can also be based on waste animal fats.

The basic raw materials for the production of pure fuels (substituting diesel oil in 100%), which can be used in appropriately designed diesel engines or for the production of biocomponents added in different proportions to diesel oil, are vegetable oils obtained in the process of pressing and extraction of seeds and fruits of oleaginous plants. Currently, the widest application in the production of first generation biofuels used in diesel engines (i.e. obtained from agricultural raw materials which may be used for food) have vegetable oils derived from seeds of soybean, rapeseed and fruits of palm oil.

… These oleaginous plants are important for world agriculture, food economy and processing industries. They are the raw material for the production of consumer and technical fats, source of food and fodder protein and some, like cotton and flax, provide also vegetable fibres[31].

In Polish conditions the basic oleaginous plant is rapeseed.

… Cultivation of rapeseed constitutes an important alternative to part of farmers specializing in the production of cereals. The demand for rapeseed for consumption for many years has remained stable at 1.0-1.2 million tonnes per year (with total crops in 2009 at 2.4 million tonnes), which at yields of 3 t/ha requires approximately 330-400 thousand ha. Ultimately, this means that crops

[29] *Rural Development Programme for 2007-2013*, MARD, Warsaw, 2011.
[30] *National Renewable Energy Action Plan*, Minister of Economy, Warsaw, 2010, p. 182.
[31] Ibidem, p. 120.

from the area of 600-800 thousand ha may be allocated for fuel without harming the food market[32].

The trend on rapeseed market, to which the demand for biofuel applied, is promising for producers while buying prices of rapeseed are ca. twice as high as of wheat.

NAPs assumes that agriculture should in the perspective of 2020 provide biomass for the power industry, district heating and refrigeration and for the production of bioethanol and biodiesel. Demand entered into the NAPs would require 3.78 million ha of agricultural land for biomass production. Use of land for the production of rapeseed (raw material for production of biodiesel) exceeds greatly the area for the production of this plant for food and fuel purposes (1.10 million hectares), while the given limit value should not be exceeded for phytosanitary reasons. Consequently, Poland will lack about 1 million ha for rapeseed production and will be forced to import substantial quantities of rape or oil, if the intended objective for biodiesel production is to be met. The demand for cereals indicated in the NAPs for the production of bioethanol can be fully covered. In the report prepared by the Institute of Renewable Energy[33] it was estimated that the area of rape for food and energy purposes should not exceed 1.10 mln hectares for the phytosanitary purposes. As a result it is expected that Poland will have to import significant amount of oleaginous crops to fulfil biodiesel production volume. On the other hand the amount of domestic cereal production is satisfactory to cover food and bioethanol demand[34].

Similar estimates are strengthened in public awareness that … *according to many Polish experts, EU forecasts are rather impracticable — even on the assumption that the yields of crops, mainly cereals, will increase in this time. The most likely scenario is that in the coming years a maximum of 1.7 million ha of land will be allocated for energy crops, including 0.5 million hectares for the*

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[32] Ibidem, p. 124.
[33] *Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii − wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020*, Instytut Energetyki Odnawialnej, Ekspertyza dla Ministerstwa Rozwoju Regionalnego, 2011.
[34] Ibidem.

production of rapeseed for biodiesel, 0.6 million ha of arable land under crops for ethanol and ca. 0.6 million hectares for energy plants. ...[35].

The considered opinions are contradictory and prove that the problem will be intensified, especially taking into account increasing percentage of biofuels in liquid fuels market. One can also expect critical opinions concerned with growth of available land for biofuel production as a result of putting them out of food production. These are complex processes and their assessment cannot use simple analogies, such as the average size of agricultural land for crop production per capita in other countries. Obviously it is not possible to significantly increase the share of agriculture to produce energy without affecting the food market.

2.3. Production of plants for energy purposes

Theoretical potential for sustainable production of biomass, according to requirements of Directive 2009/28/EC, for the power industry and district heating is 6.1 million ha of land (Table 5).

However, the technical potential is only 2.18 million ha, which remained after the elimination of the land in areas with too low precipitation, not guaranteeing the availability of ground water, protected or valuable due to biodiversity. In order to use this potential, farmers should obtain the same price for biomass as for the current production for food purposes and additional premium for risk associated with new production.

[35] *Zasoby ziemi ograniczają produkcję roślin na cele energetyczne*, WNP, 2011.12.29 http://www.wnp.pl/wiadomosci/158911.html.

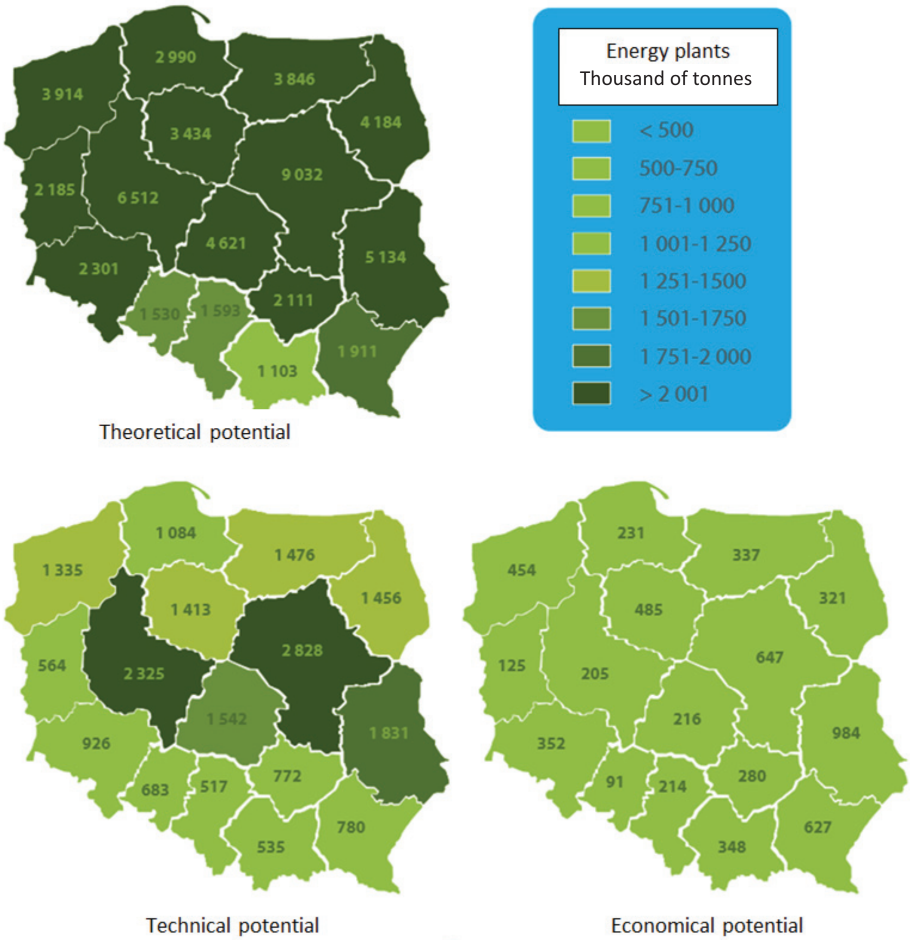
Table 5. Potential of solid biomass from perennial energy plantations

Voivodeships	Theoretical potential		Technical potential		Economic potential		
	area (ha)	biomass (t d.w.)	area (ha)	biomass (t d.w.)	area (ha)	biomass (t d.w.)	%
dolnośląskie	250 897	2 300 974	103 714	926 156	36 616	352 460	6.0
kujawsko-pomorskie	373 956	3 434 026	154 162	1 414 941	51 610	485 051	8.2
lubelskie	555 447	5 133 825	200 974	1 831 154	104 876	984 259	16.6
lubuskie	248 632	2 184 800	63 334	564 346	13 975	124 943	2.1
łódzkie	489 695	462 145	163 839	1 542 268	23 553	216 165	3.7
mazowieckie	984 526	9 032 029	307 097	2 827 822	72 944	647 053	10.9
małopolskie	111 118	1 102 847	55 567	535 248	35 136	347 952	5.9
opolskie	149 607	1 530 104	68 596	682 643	7 922	90 804	1.5
podkarpackie	203 160	1 911 378	85 862	780 063	70 042	626 662	10.6
podlaskie	481 188	4 184 227	166 156	1 455 680	40 349	321 327	5.4
pomorskie	313 280	2 989 896	115 031	1 083 780	23 899	230 890	3.9
śląskie	162 188	1 593 139	53 283	517 051	22 536	214 446	3.6
świętokrzyskie	232 218	2 110 721	85 650	771 964	30 708	279 966	4.7
warmińsko-mazurskie	419 683	3 845 645	162 240	1 476 242	35 751	336 639	5.7
wielkopolskie	717 666	6 511 796	255 083	2 324 929	24 273	205 450	3.5
zachodniopomorskie	417 379	3 914 227	144 240	1 335 131	46 534	453 984	7.7
Poland	6 110 641	56 401 092	2 184 828	20 067 419	640 724	5 918 052	100

d.w. – dry weight equivalent

Source: Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii – wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020, Instytut Energetyki Odnawialnej, Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011, p. 60.

Figure 4. Potential of solid biomass from perennial energy plantations



Source: base on IUNG-PIB publications.

This condition is met when the price offered by the energy industry is at the level of 21 PLN/GJ loco field in the area of 0.64 million hectares. This is the current economic potential of biomass production. Full use would produce 5.91 million t of dry biomass, which would cover 57% of demand specified in the NAPs (Figure 4).

In practice, in the light of the applicable regulations, the majority of the biomass from this potential can be taken over by the power industry. At current economic conditions it may pay for biomass up to 23-26 PLN/GJ loco field. Prices for district heating may be too high. The greatest economic potential of biomass is located in the voivodeships: Lubelskie, Mazowieckie and Podkarpackie the smallest in Opolskie and Lubuskie[36].

2.4. Use of waste and derived food production

Available waste is in the first place the straw (may be treated as a by-product) and waste from animal husbandry, or processing. The straw as a by-product is used in agriculture as roughage for animals, litter, substrate increasing reproduction of organic matter in soil and substrate for the production of mushrooms. After deducting demand for straw for these purposes, ca. 5.8 million t (± 30% of dry weight of straw) can be allocated for energy purposes.

Because the straw resources are variable, it is generally accepted that the power industry can effectively use 30-50% of existing resources (Table 6). The rest should be used locally. By adopting such assumptions the power industry could use from 1.74 to 2.90 million t of dry weight of straw.

The largest straw resources are located in the voivodeships: Lubelskie, Wielkopolskie, Kujawsko-Pomorskie, Pomorskie and Opolskie (Figures 5 and 6). The smallest in the voivodeships: Podlaskie, Małopolskie, Lubuskie and Warmińsko-Mazurskie.

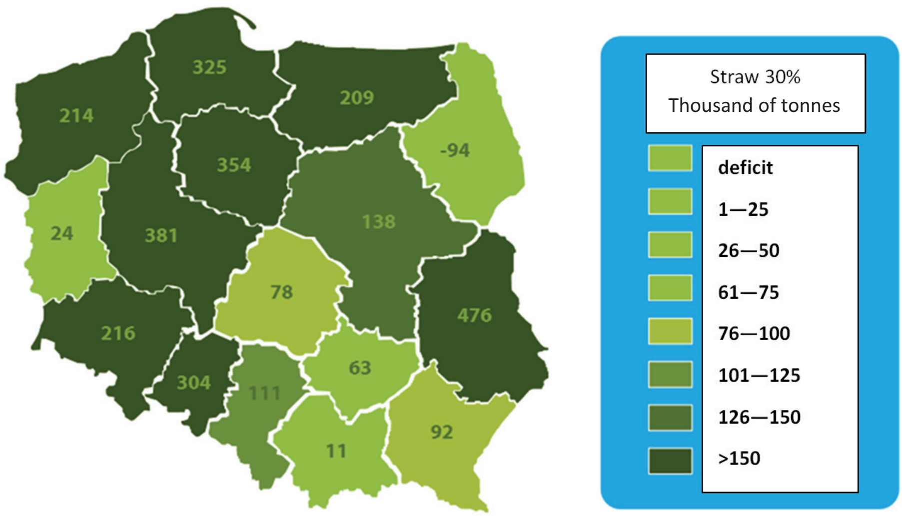
[36] *Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii - wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020*, Instytut Energetyki Odnawialnej Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

Table 6. Potential of straw unwanted in agriculture according to Institute of Soil Science and Plant Cultivation

Voivodeships	Straw	Energy utilization	
	tonnes of dry weight /annually	30%	50%
dolnośląskie	431433	129430	215716
kujawsko-pomorskie	707176	212153	353588
lubelskie	952733	285820	476366
lubuskie	48323	14497	24162
łódzkie	156396	46919	78198
mazowieckie	21244	6373	10622
małopolskie	275242	82572	137621
opolskie	608311	182493	304155
podkarpackie	184420	55326	92210
podlaskie	-188976	-56693	-94488
pomorskie	650129	195039	325065
śląskie	222183	66655	111091
świętokrzyskie	125662	37698	62831
warmińsko-mazurskie	417289	125187	208645
wielkopolskie	762543	228763	381271
zachodniopomorskie	428309	128493	214154
Polska	5802414	1740724	2901207

Source: Kuś J., Madej A., Kopiński J., Bilans słomy w ujęciu regionalnym, [w:] Regionalne zróżnicowanie produkcji rolniczej w Polsce, Studia i Raporty IUNG-PIB, nr 3, Puławy 2006.

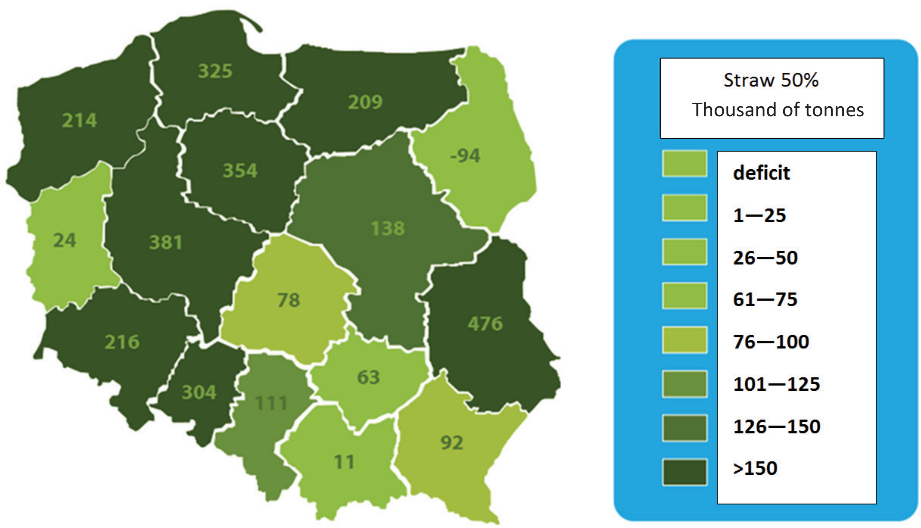
Figure 5. Quantities of straw available for energy industry
with 30% use of the potential



Source: Kuś J., Madej A., Kopiński J., Bilans słomy w ujęciu regionalnym, [w:] Regionalne zróżnicowanie produkcji rolniczej w Polsce, Studia i Raporty IUNG-PIB, nr 3, Puławy, 2006.

The main types of agricultural biomass used in the energy industry are straw and waste products of the agri-food industry. Currently, the acquisition of straw for energy industry becomes increasingly difficult, and the prices reach 200-250 PLN/t. Despite this, obtaining 30-50% potential of straw unwanted in agriculture seems possible. This situation will go on until the European Commission introduces regulations requiring agriculture to limit greenhouse gas emissions by increasing carbon sequestration in soils. Then the greater quantities of straw will be left on fields and the potential of straw available to energy industry will reduce. The use of solid biomass production potential in perennial plantations will be extremely difficult. In 2009, the area of these plantations in the country was only 10 200 ha. Farmers are not interested in the developing this line of production. Similar situation is in the EU, where in 2007, according to AEBIOM data, the area of these crops was 50-60 thousand ha. Even in countries such as Sweden, where subsidies of EUR 1000 (currently EUR 500) were paid per each hectare of willow plantations, their area is 15 thousand ha. In the UK, where these costs have been reimbursed with 1450 EUR/ha since 2007 for selected plants grown for solid fuel, the area of plantations has increased only about 2500 ha. Therefore it is likely that in Poland and in the EU the quantity of biomass from perennial plantations will not be as much as shown in the NAPs. It will be more and more difficult to get free resources of agricultural biomass for export.

Figure 6. Quantities of straw available for energy industry with 50% use of the potential



Source: Kuś J., Madej A., Kopiński J., Bilans słomy w ujęciu regionalnym, [w:] Regionalne zróżnicowanie produkcji rolniczej w Polsce, Studia i Raporty IUNG-PIB, nr 3, Puławy, 2006.

The size of the market potential of agricultural biogas, possible to achieve by 2020, in each of the voivodeships, was calculated based on data from NAPs. According to the assumptions of NAPs, the real market potential of agriculture by 2020 is 908 MW. The value of the potential can be also justified with Government plans for stronger support for this RES technology, in relation to other, in the long term and with new legislative solutions (e.g. implementation in the proposed law on RES of higher value of certificates of origin for biogas than in the case of other RES technologies).

Table 7. Market potential for agricultural biogas in MW

Voivodeships	Potential to 2020
	MW
dolnośląskie	26
kujawsko-pomorskie	73
lubelskie	55
lubuskie	14
łódzkie	47
mazowieckie	9
małopolskie	103
opolskie	29
podkarpackie	9
podlaskie	84
pomorskie	44
śląskie	26
świętokrzyskie	13
warmińsko-mazurskie	106
wielkopolskie	216
zachodniopomorskie	52
Poland	908

Source: Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii - wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020, Instytut Energetyki Odnawialnej Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

By adopting the path of development of biogas in the NAPs as a market potential and at the same time having regard to the distribution of the potential in each of the voivodeships, in accordance with the previously calculated economic potential (from proportions), the study (Institute for Renewable Energy, 2011) calculated the market (investment) potential for each of the voivodeships[37].

As a result of the adopted assumptions and analyses made, the following voivodeships may have the biggest share in the implementation of the adopted assumptions: Wielkopolskie – 216 MW, Warmińsko-Mazurskie – 106 MW and Mazowieckie – 103 MW. The list also indicates strong position of the voivodeships: Podlaskie – 84 MW and Kujawsko-Pomorskie – 73 MW. According to the above analysis, the potential of the current leader of biogas investments – Pomorskie Voivodeship – will slowly deplete[38].

[37] Ibidem.

[38] *Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii - wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020*, Instytut Energetyki Odnawialnej, Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

2.5. Renewable energy sources neutral to food production

The use of wind and solar energy is considered an attractive alternative of utilization of agricultural area − the primary factor of production in agriculture − for production of renewable energy. This is confirmed by increased use of this type technologies on farms worldwide. However in particular, the developed countries are most advanced in the development and application of modern wind and solar technologies.

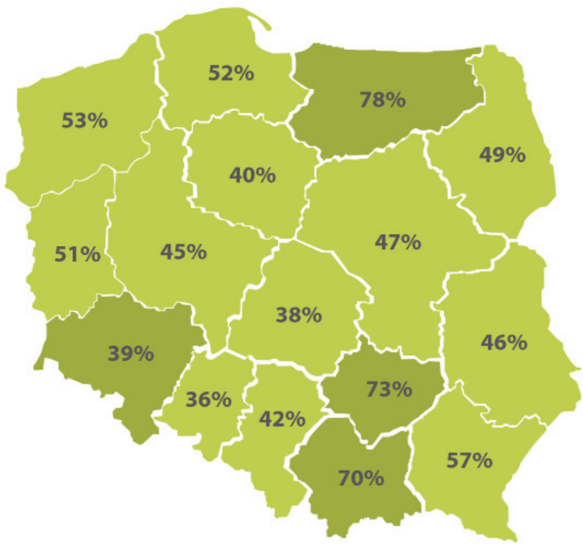
Wind energy

Wind power is a kind of RES, which is growing the fastest in recent years in the country. Until the year 2012 the most common high-power wind turbines were of more than 1 MW, grouped in wind farms. According to the NAP role of wind energy in renewable energy technologies will be significant, and the current development of onshore wind farms will be followed with development of small wind power generators. From the point of view of agriculture, especially small wind energy systems it can be an interesting option, and bringing additional income for agricultural households. However the administration procedures related to installation were main obstacles for development of small scale investments. Therefore the most active were specialized companies that were based on lease of land from farmers.

Despite the controversy, under the NAPs, it will play a leading role in the implementation of 15% of the objective for OZE in 2020 in its part on green electricity. However, note that in accordance with the proposal in the NAPs, the further development of the leading generation of wind power in land-based wind farms, will be supplemented by quick development of small wind energy (important technology for all regions) and offshore wind energy (important for Pomorskie Voivodeship and, until 2020, to a slightly lesser extent for Zachodniopomorskie Voivodeship). Wind energy is not a uniform technology and its potential was estimated with the division to different technology classes.

According to available sources[39], it can be stated that ca. 4% of the agricultural land in Poland is suitable for technical use for wind energy. Further estimates assumed (according to EWEA) that the demand for space in the modern wind power industry is 10 ha per 1 MW of installed capacity. These indicators are valid for land-based wind farms.

Figure 7. Share of areas where the location of wind farms on the surface of agricultural land may be limited



Source: Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii – wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020, Instytut Energetyki Odnawialnej, Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

[39] *Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii – wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014-2020*, Instytut Energetyki Odnawialnej, Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

An important spatial limitation for wind energy development, and in particular for land-based wind farms, is the existence and growth of protected areas, including NATURA 2000. It should be noted that protection does not exclude, at least in some cases, the location of wind farms; however, the final decision is up to the local and regional authorities. However, for methodical purposes, further calculations adopted a sharp criterion, assuming that all protected sites will be excluded from wind energy development. In addition, other exclusions were added due to possible difficulties in locating wind farms in buffer zones of protected areas or on densely populated areas. Depending on population density and fragmentation of farms on a given area, they constitute from 15 to 40% of land (results of the SIWERM project). As a result, it was found that on 50% of agricultural land, where it was possible to use wind energy, investing could not be implemented or would encounter significant difficulties. This indicator, however, varies greatly in different regions, ranging from 36 to 78%. Most greatest restrictions are in the North and the South of the country, due to overlapping areas of high wind speeds and areas subject to protection (Małopolskie, Świętokrzyskie, Warmińsko-Mazurskie), and due to the fragmentation of agricultural holdings and the difficulty in micro-location of turbines, associated with fragmented settlement development (e.g. Podkarpackie).

In domestic conditions, taking into consideration the costs and the support system, small wind power plants are one of the most promising technologies of dispersed generation and micro-generation (in the current decade still more attractive economically than e.g. photovoltaic systems). In the context of the programming of EU funds for 2014-2020, and in particular the essential part of the cohesion policy relating to regional development (ERDF), small wind power plants have to play a much greater role in Poland than it would result only from the installed capacity. They are elements of micro-network, smart energy networks and prosumer part of distributed generation, especially in the agriculture sector.

However, it should be pointed out that their actual, potentially very important role in the development of new technological concepts and creating a new model of energy in rural areas will depend on key political decisions and changes in the legal environment, with regard, for example, to possible taxation of farmers on general rules (the applicability of aid rules and taxation support instruments) and determination of the dividing line between support for agriculture (CAP) and other instruments of support (including investment grants).

Solar energy − heat

Solar energy resources are much greater than renewable energy resources available in Poland. Therefore it is hard to find a common denominator when comparing them with other resources in the energy balance, especially in the short and medium term. The most appropriate methodical approach in such a situation seems to be the assessment of the potential of selected technologies, possible to apply in a given period − solar energy inverters − in specific energy carriers in specific applications. Currently, the most popular use of solar energy is the use of solar collectors for heating water, in particular in single family houses (to a lesser extent to heat water in hospitals and other health care facilities). Solar water heating technology became the most popular of all RES technologies under the previous calls for proposals to ROPs. In the next financial perspectives of 2014-2020, it will be feasible to use solar panels also for other, more advanced applications in different beneficiaries.

With regard to methodical terms, the solar thermal energy is to be considered and assessed by using the model of the "demand side", i.e. the evaluation of the possibility of applications for specific needs (and not just the "supply" of solar energy). The most important energy needs (heating), which are the background for solar energy development in Poland in the period to 2020, and in the next decade, are:

- hot water in housing,
- central heating in housing,
- hot water in services and public sector,
- central heating in services and public sector,
- technological heat in industry and agriculture,
- solar cooling in housing,
- solar cooling in services.

The calculations of the real potential of solar energy for hot water were based on data on allocation for the voivodeships, different technical and economic conditions for installing solar panels and building types. The analysis made use of the publication of households situation by the Central Statistical

Office[40]. The economic potential of heat for hot water was calculated on the basis of the number of people using hot water. Only the systems in which hot water is not purchased from district heating networks were taken into account, and those in which there was no (apart from heating water on kitchen tabletops or using water-heaters) heating systems for hot water. Systems, in which hot water is purchased from the network were omitted because the tariffs for the network heat have too high proportion of fixed costs and cost savings when purchasing hot water from the outside would be insufficient trigger for the economic use of the “solar” option. With these assumptions, the total number of people that could benefit from the preparation of hot water using solar installations is more than 32 million people in permanent residence. The economic potential of the solar collectors to heat water was calculated on the assumption that they provide during the year 60% of the energy needed for its preparation. This gives a result of 43 000 TJ/year.

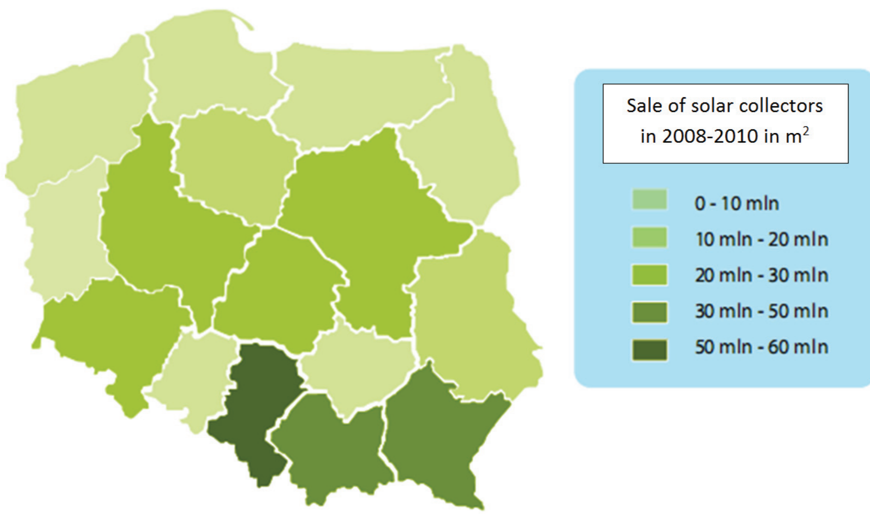
The calculation of the market potential for 2020 adopted, on the basis of studies for other countries (e.g. Austria) and European studies (e.g. ESTIF), the rate of its use at the level of 1/3 of economic potential, which is the equivalent of 14 193 TJ of final energy and the required area of solar panels of ca. 12 million m^2 in order to prepare hot water. The potential of the “combi” systems was estimated on the basis of usable area in individual flats in permanent residence facilities suitable for this type of application. The study took into account only systems with individual heating systems and furnaces. The total usable area in flats that allows for collaboration between traditional systems and panels under such assumptions is 545 million m^2 (70% of the total residential area used continuously). In addition, the study assumed the maximum possible degree of the use of solar installations in “combi” systems, which is 24%. Having regard to the unit cumulative energy demand in buildings, which will use solar energy in 2020 at 360 MJ/m^2, and assuming that all installed “combi” systems will also serve to prepare hot water (part of the potential has already been included in the analysis above), the economic potential of these systems (excluding the part included above for hot water), is 47 144 TJ. However, in comparison to the potential of solar energy for hot water, the study adopted much lower rate of using the economic potential by 2020, at 10%. With these assumptions, the market potential of “combi” systems is 4 700 TJ of final energy and requires

[40] Poland Household Budget Survey 2006-2008, Central Statistical Office, Warsaw, 2009.

nearly 2.6 million m^2 of solar collectors. In this case one should apply vacuum collectors for greater efficiency in the winter half of the year.

The potential of solar systems for cooling the premises was estimated on the basis of the useful floor area of sales and service buildings. The total usable area meeting the above conditions stood at 2.6 million m^2. The maximum possible share of solar installations in the cooling systems was adopted at 70%. Degree of use of solar energy in order for cooling premises in 2020 was established at 2%. With these assumptions, market potential of solar energy systems is 3.7 TJ of final energy and requires ca. 2 thousand m^2 of solar panels.

Figure 8. Sales of solar collectors in Poland in 2008-2010, by voivodeships, in m^2



Source: Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii – wnioski dla Regionalnych Programów Operacyjnych na okres programowania 2014--2020, Instytut Energetyki Odnawialnej Ekspertyza dla Ministerstwa Rozwoju Regionalnego 2011.

Due to the growing demand, dynamic development of domestic production of solar collectors and systems are observed. This new market includes part of the heating system and installation industry, which in addition to production takes into account trading and installation companies.

In the context of agriculture the possibility of using solar panels is primarily connected with on farm use for water heating. The advantage in this case is usually more advantageous location of collectors. The development potential also resides in the agricultural industry, which requires increased amounts of heat, e.g. for drying.

Solar energy − Photovoltaic

The main challenge for the use of solar energy to generate electricity is the economic efficiency of photovoltaic systems. Factors that influence the effectiveness of these solutions are the cost of purchase (investment expenditure), plant capacity and geographical conditions.

The current national target for the development of photovoltaic (PV) systems in 2020, as proposed in the “Polish energy policy 2030” of 2009 and confirmed in the "National action plan for renewable sources of energy", has been established at merely 3 MW of installed capacity. Lack of adequate support for this technology in the national regulations (the system of technologically undifferentiated green certificates in energy law), practically would not give a chance for rational planning for proper support to this technology under EU's regional funds in the financial perspective 2014-2020. It would be risky to assume that photovoltaic systems connected to the network will achieve the same threshold of profitability, based on the fast drop in technology costs across the world and the simultaneous rapid growth of prices for electricity in Poland (so called grid parity), where even moderate support from ROP would allow rapid development of the market in 2014-2020. Lasting effects in the development of photovoltaics can be brought by the proposed Act on RES, which proposes guaranteed fares and relatively high, compared to other RES technology, correction factors for solar photovoltaic installations. There are also plans to facilitate connecting installations to the energy network to work in the “on-grid” mode[41].

The agricultural sector in such a scenario would be one of the main beneficiary. Photovoltaic systems require large areas (measured in hectares for installations with a capacity of 1 MW and above). In the case of farms the installation can be placed on the roofs of farm buildings with favorable exposure (south). The electricity can be consumed on the spot and given back to the network in

[41] The proposed solution is among others to enable, without unnecessary administrative procedures, to connect to the network at a level equal to the maximum ordered power.

part or all of the excess. In the first case, the farm is a very good example of the concept of prosumer.

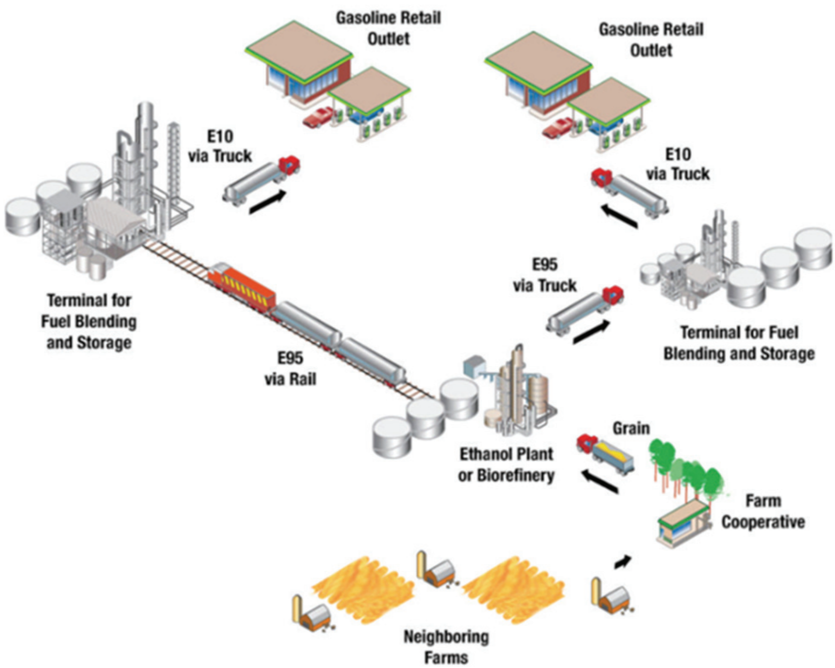
2.6. Logistic issues related to biomass production for energy purposes

The problem of delivery logistics in the report of the International Energy Agency, IEA, is shown from the point of view of barriers to passing from first-generation biofuels to second-generation biofuels. The authors suggest that *...there are no model solutions on how to cost-effectively deliver raw materials to large production plants. The existing systems for the collection, storage and transport of raw material for the scale allowing production large quantities of biofuels are not efficient. The lack of experience in the functioning of large scale biorefineries requiring delivery of large quantities of raw material poses a problem for the development of costly infrastructure when the currently used facilities are insufficient. When demand for the raw material/biomass will be visible, the infrastructure will begin to develop; today we can say that this is a "chicken and egg" problem. Production and supply of the raw material require a significant investment in the entire chain of supply and conversion and distribution processes. Many experiences can be adopted from the sugar industry ...*[42].

According to the report on the RENEW project[43] ... *the cost of logistics for the raw material depends on the transport distances, road infrastructure and carrying capacity of trucks. Therefore, potential density of biomass covering yields per hectare of land and concentration of production areas have a large impact on the costs. In areas with promising potential production of raw material, costs are estimated at 1-2 EUR/GJ ....*

[42] *Technology Roadmap. Biofuels for Transport*, IEA, OECD, 2011.
[43] *Biomass provision costs*. Final report, RENEW, report D.5.3.6, 2007.

Figure 9. Structure of supply chain for production and distribution of ethanol



Source: Unites States Department of Agriculture, 2007, p. 22.

Availability of renewable raw materials depends on the supply from sectors: forestry, agriculture, agri-food processing and industrial, which generate waste classified as waste biomass.

Logistic solutions developed in agriculture for traditional crops (e.g. sugar beet, rapeseed) and those used in forestry are efficient and cost effective. Experience with these raw materials can be transferred to some extent to new applications, for example, to plants grown for energy purposes. The total cost of the delivered raw materials consists of the costs of collection, initial processing (e.g. forestry waste, straw baling), transport including loading and unloading.

The structure of the costs is affected by supply chain organization, which depends both on the available equipment and applicable organizational solutions. For example, the cut down trees can be pulled and processed by the road (sorting, removing branches). As a result, forestry wastes are more readily available than in the situation when the waste remains in the clearing. The Scandinavian countries have worked out the best solutions in Europe to sourcing and managing the wood.

When organizing supplies of renewable raw materials for producers of energy with demand measured in hundreds of thousands of tonnes, we should bear in mind the following factors:

- Renewable raw materials have a lower density when compared to fossil fuels. This is caused among others by high humidity (up to 60%). Raw material density increases by crushing, baling, binding in bundles, etc. The key is to reduce the water content for lower transport costs and improved physical properties, which is important for further processing operations.
- Economic efficiency of energy producers increases with production volume. On the other hand, the unit costs of renewable raw materials (portfolio) generally increase with increasing volume due to longer transport distances. The relationship between the positive economies of scale of the production and the increasing cost of the portfolio (including due to distance) determines the economic optimum of production volume. Advanced pre-processing technologies such as compacting (pelletisation, baling) or termochemical processing (e.g. pyrolysis) allow reduction of the costs of transport over long distances (over 100 km) and as a result affect the economic optimum of production volume. Figure 10 shows organization scheme of logistics using pyrolysis process.
- The organisation of supply of renewable raw materials is affected by their seasonal availability and by storage capabilities. For example, in Polish climate conditions, beet reaches maturity after 160-180 days of vegetation, counting from the date of sowing; it should be harvested from the middle of October to early November. Organisational solutions, e.g. used in biorefineries, include buying up raw materials in season and storing in own warehouses. Another one involves keeping contracted raw material at suppliers. Storage possibilities depend on moisture content of raw materials. If it is higher than 20% there is increased loss of dry matter and increased

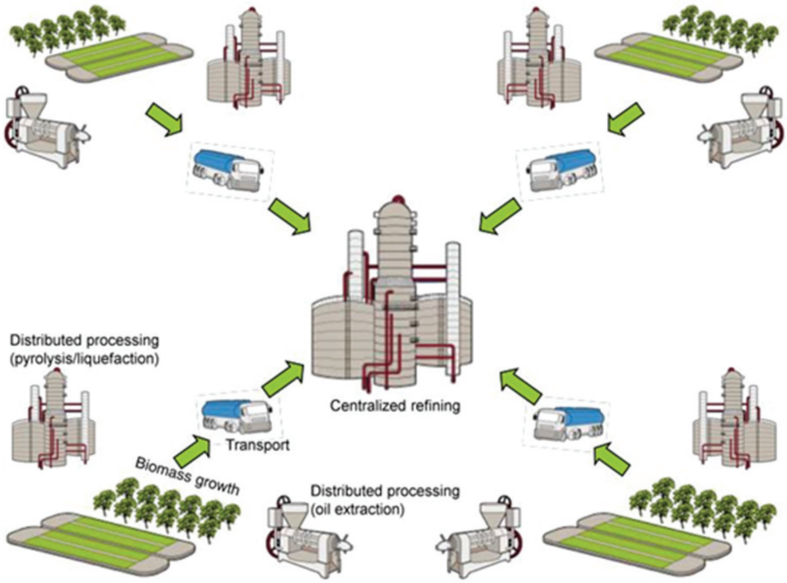
risk of self-ignition and the processes of decomposition may exacerbate. The problem can be partly solved by the use of pre-processing.

- In the context of the demand for raw materials, transportation costs and density (e.g. pellets, rapeseed oil, bioethanol), the sea transport is economical. In Polish conditions an example is the import of wood pellets from Scandinavia or the import of bioethanol. Low energy density of renewable raw materials processed into the form of wood chips, or bales, which are transported by road, causes that this type of transport is usually cost effective to 100 km.

Examples of theoretical work, which precedes practical implementation, including proposals of the organization system for agricultural biomass processing are for Lubelskie Voivodeship: … *before the creation of a greater number of biomass processing plants (briquetting plants and pelleting plants), there is the time to discuss and prepare the biomass processing model. The authors present the proposal for a comprehensive organization of buying, processing and supplying agricultural biomass/solid biofuels of agricultural origin, taking into account the needs of the power industry, agricultural structure of Lubelskie Voivodeship and diversity of crops. Large land fragmentation is a factor that makes it difficult to overcome economic peripherality. According to the authors, there are opportunities to minimize the importance of this factor provided that the proposed solutions are implemented ...* [44].

[44] Dobrowolski J., Łepecki A., & Łepecki Ł. (2001). *Propozycja organizacji sytemu przetwórstwa biomasy rolniczej na terenie województwa lubelskiego*, Barometr Regionalny (3(25)), 51-58.

Figure 10. Concept of logistics organization using pyrolysis



Source: Adapted from Wright, M. M., R.C. Brown, A.A. Boateng. 2008. Biofuels Bioproducts, Biorefining 2:229-238. http://bioweb.sungrant.org/General/Biopower/Technologies/Pyrolysis/Pyrolysis+Oil/Pyrolysis+Oil.htm

The proposed organisation of biomass/biofuels for energy industry implies:

- the use of the potential of biomass to supply power plants and thermal power station, and not biogas plants or distilleries,
- introduction of an intermediary between farmers and the final recipient (e.g. plant) by organizing a dozen/several dozens of biomass processing plants, the so-called Local Biomass Processing Centres (LBPC),
- the deployment of LBPC to reduce the distance between the most distant field and the processing plant to ca. 10-15 km,
- operation of LBPC leading to the unification of diverse material and preparation (primarily compacting) to reduce the costs associated with the transport to the recipient,

- buying any kind of agricultural biomass, regardless of the area,
- lack of technical limitations concerning the bought biomass (straw and hay bales and cubes of any size, the remaining biomass also in bulk),
- the widest possible use of machinery and equipment owned by farmers (collection of straw, transport from the field to the LBPC, and in some cases the storage of straw).

The main task of the company supplying biomass for energy industry is to maintain liquidity of supply during the whole year, despite the seasonality of raw material, which is mainly straw. It is also important to eliminate supplies of agricultural biomass with quality parameters which may give rise to technical problems in the process of co-combustion with coal (e.g. to large contents of chlorine). For example, the supply of biomass (agri-briquette) with unstable dimensions (too large size of biomass particles in the briquette) may impede its supply to the burner or cause incomplete combustion in Dutch ovens with fluid bed. The investor managing the LBPC network, when determining on behalf of energy industry, i.e. the specific recipient of this sector, the method of processing and storage of biomass and the composition the biomass stream for the boiler, can regulate these parameters before the agri-briquette or agri-pellet goes to the boiler. Such actions will help avoid congestion of the biomass (on the storage yard of power plant) that does not satisfy the conditions expected by energy industry. The multifunctionality of the system will also allow, in the case of system failure or downtime, keeping adequate supply liquidity through modulation of the processing performance of individual centres and the use of their storage capacity.

Critical issue in logistic system is to ensure the compatibility of biomass collection and processing systems with biomass storing and feeding system. This poses specific requirements for the lines for the production of agri-briquette to ensure:

- repeatability of the shape of fuel,
- processing of biomass in any form (small cubes, round bales, large cubes, bulk),

- adjustable fineness of raw material to be compacted,
- adjustable degree of compacting, depending on the requirements of specific recipients.

This will allow for the introduction of a more efficient transport system compared to existing solutions, most of which produce biofuel in the shape of a cylinder. At present, loading agri-briquettes in the shape of a cylinder is done by loaders, which pour bulk biofuel on dumpers. The weight of the load obtained in this way most often does not exceed 16 tonnes. The proposed solutions give this possibility.

The typical supply chain for biorefineries involves the basic processes, specific to agri-food processing and fuel industry. Considering the typical location of the raw material (e.g. farms, forests) transport infrastructure generally involves road transport as the only potential means to collect and transport the fuel. Other arguments for the use of those means of transport are the relatively short distances and greater flexibility of road transport in comparison to other options. Means of transport such as barges and railway have to be considered for large distances.

The basic processes relating to delivering raw material to biorefinery are:

- collecting the raw material on the field,
- transportation to the storage,
- handling and storage,
- loading and transport to buying station,
- transport to processing facility or biorefinery,
- conversion of the raw material into intermediate in order to raise the efficiency of transport.

The factors that distinguish the supply chain to biorefinery from other supply systems are the seasonality of supply and low energy density. Season in which the raw material is available is limited and determined by harvest time, weather conditions and land management. Consequently, one must store large quantities of raw materials in the long periods of time, to ensure a constant supply over the year. The low density of the material resulting from the high humidity requires more storage space; one should engage more means of transport and as a result the logistic costs grow.

Elstar Oil S.A. refers in the financial statement to the seasonability risk of the supply of raw material and the risk associated with agricultural production: the supply of rapeseed in Poland is affected by weather conditions throughout the production period for rapeseed – the threats include freezing in winter, drought in spring and prolonged rainfall during harvest. From the Company's point of view, seasonability of raw material supply causes the need to accumulate raw material in a relatively short period of rapeseed harvest during the summer and storing significant stocks to ensure continuity of production over the year. In this connection, the Group raises an operating loan to finance purchase of the raw material.

The issue of organization of biomass supply has a practical and engineering character. The current situation in Poland is characterized by:

- a high proportion of co-burning as the dominant use of biomass and oversupply of certificates of origin, and consequently inhibition of the development of other renewable energy sources in Poland;
- the highest share of forest biomass at systematically increasing share of biomass of agricultural origin;
- balancing the supply of raw materials for bioethanol production and the anticipated shortage of domestic rapeseed production devoted to the production of esters;
- imports of biomass from abroad and of biofuels;
- planning to introduce a system of certification of origin and biomass production sustainability criteria.

The issue of supply logistics in Polish conditions is reduced to optimize already existing chains. However, the change of the paradigm to preferentially support centralized production (co-burning) to promote micro generators results in reconstruction of supply chain. In this case, supply chains will shorten and simplify, due to limitations in the volume of biomass transported over long distances, including imports.

Development of models of production and management of agricultural biomass is challenging and requires an interdisciplinary collaboration of experts in the field of agricultural engineering, agricultural economics, urban planning and energy technologies. Based on the study of literature one can only sketch the outlines based on general assumptions related to the current situation of formal and legal in Poland. With the development production and development of biomass in the agricultural sector the size of the production and support system should be taken into account. A model production volumes will follow more of a support system than with a mechanism to reduce costs due to economies of scale. As mentioned, biomass has a relatively low energy density and consequently high unit costs of logistics, which makes transport distances, the availability of biomass in the environment of the company, may be the primary criterion for determining the volume of production. In other words, the location of the property in the concentrated area will allow an increase in biomass production. As a result, production systems should be considered: centralized demanded large amounts of biomass and decentralized which is based on local resources. The second system, combined with support for the production of electricity, can make farms not only suppliers of biomass, but also active participants in the energy market. This is undoubtedly an opportunity for farms, which is consistent with and fits into the concept of sustainable development and multifunctional agriculture.

Current state and challenges for support mechanisms

The current system of supporting electricity generation from renewable energy sources is mainly related to the so-called "green certificates". The mechanism of "green certificates" for enterprises producing electricity from RES is bi-directional and consists in compulsory purchase of the energy (with the exception of the purchase of electricity produced from agricultural biogas) and the issue by the President of the Energy Regulatory Office (ERO) of the certificates of origin (Renewable Energy Source – RES), which can be traded on the Polish Power Exchange (PPE). The mechanism of support to enterprises producing electricity in high cogeneration (Combined Heat and Power – CHP) consists in obligatory reception, transmission or distribution of electrical energy produced by the operator of the distribution system, with reliability and safety of the public power system, and the issue by the President of the ERO of the certificates of origin and certificates of origin from CHP cogeneration, that can be traded on PPE[45].

The primary type of certificates is the so-called certificate of origin of electricity produced in RES, i.e. green certificates. The value of the green certificate corresponds to the value of the replacement charge determined by the President of the ERO every year by 31 March. The basis for determining the replacement fee is the amount of 240 PLN/MWh. In 2010, the value of replacement fee corresponding to the green certificate was 267.95 PLN/MW and was determined on the basis of the basic value updated according to the growth of inflation rate. The system of certificates of origin additionally rewards producers of energy in cogeneration, who are entitled to yellow, red or purple certificates as well. Yellow certificates can be granted to operators of the cogeneration units with total capacity not exceeding 1 MWe. The value of the replacement fee corresponding to the yellow certificate must be in the range of 15-110% of the average sales price of the electricity from the year preceding determination of its value. Red certificates may be granted to producers of energy in cogeneration in biogas plants with installed capacity of more than 1 MW. Replacement fee corresponding to the red certificate must be within the range of 15-40% of the average sales prices of electricity. Purple certificates are granted to manufacturers of energy in cogeneration units fired with methane from mines or with biogas. The price of replacement fee corresponding to the purple certificate must be in the range of 30-120%.

In accordance with the Energy Law, an energy company engaged in the production of electricity or its marketing and selling electricity to final customers is required to obtain and submit certificates of origin of electricity produced in RES to the President of the ERO for remission or to pay a replacement fee. The support system introduced in Poland, which is a formula of the so-called green certificates, is a market mechanism conducive to optimal development and competition. By separating certificates of origin of electricity produced in RES from physical energy, it is possible to trade property rights arising out of those certificates on the exchange.

[45] *Sprawozdanie z działalności Prezesa URE w 2010*, [w:] Biuletyn Urzędu Regulacji Energetyki, 2 (76), URE 2011 p. 53-54.

In addition to this mechanism, as a consequence of separating physical flow of electricity from certificates of origin, energy companies acting as sellers *ex officio* are required to purchase the entire energy as electricity produced in OZE, connected to the network in the area of the seller, for the average price of electricity in the previous calendar year, as determined by the President of ERO.

Additional incentives for the development of renewable energy sources are:

- reduction by 50% of the actual cost of connecting to the grid for RES up to 5 MW,
- obligation of the operator of the power system to ensure precedence in providing services of transmission of electricity from RES,
- release of energy companies generating electricity in RES with capacity below 5 MW from charges for licence and fees associated with obtaining and registration of certificates of origin confirming that electricity is produced in RES.

An important element of support for renewable energy is also the exemption from excise tax on energy produced in RES. In order to illustrate the costs resulting from the functioning of the support system, Table 8 presents volume – weighted average prices of property rights (for 1 MWh) in 2005-2010. Prices have been calculated from session transactions on the property rights market of the Polish Power Exchange. Table 9 presents amounts of replacement fees.

Next to the system support mentioned above, there is also a direct financial support for the implementation of investments related to renewable energy, among others, from the EU, mainly from the Operational Programme Infrastructure and the Environment, in particular under priority IX “Environment-friendly energy infrastructure and energy efficiency”. The Programme is to reduce impact of the energy sector on the environment, as well as to increase efficiency of generation, transmission and distribution of energy, improve energy efficiency in the use of energy and increase the use of energy from renewable sources measures related to the development of renewable energy sources are available both in the framework of the Operational Programme Innovative Economy, as well as the Rural Development Programme 2007-2013.

Table 8. Volume-weighted average prices of property rights in 2005-2010

Year	Instrument PMOZE*, PLN/MWh	Instrument PMOZE_A**, PLN/MWh
2005	175.00	instrument unlisted
2006	221.26	instrument unlisted
2007	239.17	instrument unlisted
2008	240.79	instrument unlisted
2009	247.28	267.10
2010	255.51	274.49

* PMOZE instrument for economic rights relating to the certificates of origin confirming production of electricity in RES in the period until 28 February 2009, ** PMOZE_A instrument for economic rights relating to the certificates of origin confirming production of electricity in RES in the period from 1 March 2009. Depreciation of property rights in the PMOZE_A instrument allows the return of excise duty of 20.00 PLN/MWh.

Source: Base on: Ministerstwo Gospodarki, 2011, za TGE S.A.

Table 9. Amounts of replacement fees in 2006-2010

Specification	2006	2007	2008	2009	2010
Amounts of replacement fees in PLN	1 958 654	88 990 383	286 267 290	470 333 755	441 063 448

Source: Based on Ministerstwo Gospodarki, 2011, p. 19 after NFOŚiGW.

Table 10. Scope of the obligation and amounts of replacement fees for individual certificates

Year	Certificate green		Certificate yellow		Certificate red		Certificate violet	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
2008	7.0	248.46	2.7	117.00	19.0	17.96	x	x
2009	8.7	258.89	2.9	128.80	20.6	19.32	x	x
2010	10.4	267.95	3.1	128.80	21.3	23.32	x	x
2011	10.4	274.92	3.3	127.15	22.2	29.58	0.4	59.16
2012	10.4		3.5	128.80	23.2	29.30	0.6	60.00

(1) scope of obligation, %, (2) amount of replacement fee, PLN/MWh

Source: Information gathered and published by P4B, http://www.p4b.com.pl/j/ .

Financial support from the EU can be also granted in the framework of the Regional Operational Programmes (ROPs), for which individual voivodeships are responsible. Funds can be given for projects related to the construction of units that use all known types of renewable energy. The regions apply the competition procedure for choosing projects for funding.

Following the recommendation of the Polish Government set out in the Stability and Growth Plan in 2009, the National Fund for Environmental Protection and Water Management (NFEPWM) has developed a programme to support investments in renewable energy sources and high cogeneration facilities. Funds for the implementation of this programme come from fees and penalties paid by entrepreneurs on the separate account of the NFEPWM.

National market of biofuels is developing thanks to the mandatory targets imposed on fuel companies under National Index Target and the accompanying support mechanisms. The obligations result from the climate and energy package; for Poland, the share of biofuels, including biocomponents, in the fuel balance is to be 10% in 2020. According to designated National Index Targets, NIT, the share of biocomponents in liquid is to systematically grow to 8% in 2015 and the aforementioned 10% in 2020.

NITs are to be implemented by entrepreneurs carrying out economic activity in the field of production, import or intra-Community acquisition of liquid fuels or liquid biofuels, who sell or market them in any other form on the territory of Poland or consume for own needs.

The biomass produced by the agricultural sector is the subject of oversupply of certificates of origin. Large scale biomass co-combustion power plants generate great, local need for biomass of agricultural origin. The current shape of the support system with trade in certificates of origin carries risks for these power plants. The expertise of the Institute for Renewable Energy prepared on order of the Ministry of Economy found already in 2011, that due to the nature of RES technology, most of the negative effects will apply to wind energy and agriculture biogas sector. Both of these technologies, including new cogeneration installations for biomass, at the current production costs (taking into account in particular the bank costs) will not survive on the market without additional support in the form of a certificate of origin of a particular value (this can be a declining value, but it should be better defined and much more predictable than the current mechanisms of the certificate market). A risk factor is also, especially in the case of wind power, the fact that these investments are burdened with repayment of commercial loans contracted in commercial banks, assuming revenue from two sources − the sale of energy and the certificates of origin. Disturbance of RES market caused by the lack of opportunities to sell certificates of origin or by the decrease of their prices to the difficult to estimate level could lead to bankruptcies in the sector and increase of bad loans. Consequently, financial institutions could withdraw for a long time from the financing of renewable energy, and the market would lack the capital necessary to implement investments for achieving the objective for 2020.

The experts recommend[46], among others, to introduce correction factors binding quantity of certificates of origin with the amount of produced energy to the Act on renewable energy and its implementing provisions, taking account of the reasonable costs of producing energy from RES, in particular the reduction of support for co-combustion in the form of correction factor not more than

[46] Wiśniewski G., Michałowska-Knap K., Arcipowska A. *O niezrównoważonym wykorzystaniu odnawialnych zasobów energii w Polsce i patologii w systemie wsparcia OZE. Propozycje zmian w podejściu do promocji OZE i kierunków wykorzystania biomasy*, Ekspertyza dla Ministerstwa Gospodarki, 2011.

20%, which corresponds to the reasonable costs of energy production in this technology. In addition, they propose exclusion of small renewable energy sources (below 5 MW) from the system of certificates of origin and covering them with fixed price mechanism (with the possibility of corrections taking account of technology developments) for a period of 15 years. Recommendations were reflected in the draft Act on renewable energy sources.

Summing up the importance of the conversion process as part of the conversion of biomass energy to produce heat and electricity should be stressed. The combustion of biomass products that involves initial gasification takes place in both the low-power boilers used in domestic heating, as well as in commercial power plants. Conversion processes in the manufacture of physicochemical and biological processes for production of bioethanol are on the other side applicable rather on an industrial scale. In terms of agricultural land devoted to the production of biomass numerous publications include divergent opinions. This demonstrates the complexity of the issues and the need to develop a solution in implemented systems related to quality, origin of biomass and the effect of environmental (sustainability criteria). It should be however concluded that it is not possible to significantly increase the share of agriculture to produce energy without affecting the food market. Agricultural land should therefore be managed in a way that ensures the highest possible food-energy yield in relation to the surface. This puts in a particularly favourable light RES technologies that are not sensitive for agro-climate conditions and not compete on production resources used for food production like wind and solar based technologies. The possibilities of using solar panels in agriculture and rural areas are seen through the prism of use for water heating, especially in the enterprises, which require large amount of heat, such as drying and various agro-tourist farms. In the case of the development of the prosument model energy agricultural sector (farms) would be an active participant in producing electricity with the use of photovoltaic and wind power technologies.

The current model of support for renewable energy should be recognised as preferential for centralized energy production. Changing the emphasis of support for renewable energy technologies toward micro-generators will force a change of the existing logistic solutions, which should be simplified. The need to change the current support system and improve position of micro-generators is confirmed by problems related with oversupply of certificates of origin.

3. Results of Norfolk farms against other farms

Currently, one of the main topics related to the sustainability of agriculture is the search for such systems of agricultural production and the choice of such agricultural practices that are both cost-effective and environmentally safe, as well as socially acceptable. There is also an increasingly strong emphasis on sustainable development in economic strategies, as well as in agricultural policy in all parts of the world, including the EU. Ensuring agricultural productivity in the long run is also very important, especially in an era of scarce resources and the economic crisis. In light of these considerations, it seems necessary to change the methods of production and farm organizations.

Ensuring profitability for agricultural producers who pursue or choose to adjust their holdings to follow the concept of sustainable agriculture is a key issue, because its implication depends to a large extent on the acceptance of farmers, since they directly introduce new farming techniques, innovations to their farms. If they do not achieve an adequate level of income they will not put into practice the assumptions drawn from the concept of sustainable agriculture. W. Michna also found that without achieving a balance between social and economic sphere it is not possible to achieve a sustainable ecological balance[47].

Thus, the analysis of farms that use crop rotation as an example of potentially environmentally sustainable farms that ensure agricultural land productivity against conventional farms will determine the characteristics of these farms. The study will also determine whether the potentially environmentally sustainable farms are also sustainable in the economic sphere.

Often when thinking about progress in agriculture one thinks about modern cultivation technologies, modern machinery, industrial fertilizers, genetics, but progress in agriculture could also be based on better learning and use of plant biology and changes in the soil which occur because of that and because of hu-

[47] Michna W., *Jakość surowców rolnych i żywności jako ważny składnik oceny zrównoważonego rozwoju rolnictwa*. Pamiętnik Puławski No. 120(II), 2000.

man activities. However, progress is expressed in the applied agricultural technology, the high yields – i.e. productivity and the method of managing them[48].

An example of such an approach may be the use of crop rotation on the farm. With the knowledge of the proper sequence of crops – that is, their biology, and strict adherence to the principles of crop rotation and agricultural technology, it is possible to improve productivity in a natural way. The use of crop rotation also plays an important role in protecting plants against pests and diseases, reduces excessive growth and reproduction of weeds, favours better nitrogen supply by including legumes in crop rotation and increases the humus content in the soil.

The effect of non-compliance with rotation principles, or their simplification, often leads to a gradual decrease in the humus content, resulting in reduced capacity to store water and nutrients in the soil, weed growth, emergence of pests and diseases. The negative environmental effects also include leaching of nitrogen into groundwater and soil erosion. A direct consequence for the farmer is the decrease in quality and quantity of crops, and this contributes to the decline in income from agriculture, not to mention the unnecessary burden to the environment.

The principle of correct rotation[49] consists in planning the sequence of plants so that plants that improve earth structure, such as perennials forage plants (legumes and their mixtures with grasses and grasses in field cultivation), as well as legumes and catch crop ploughed as green manure, alternate with plants that lower soil fertility, such as roots and maize[50]. Crop rotation is seen as a central element of agricultural technology which determines the maintenance of soil fertility in biological, physical and chemical terms. Thus it creates favourable conditions for the growth and development of plants under limited consumption and efficient use of costly fertilizers and pesticides, the use of which is also a threat to the natural environment[51].

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[48] Roszak W., *Ogólna uprawa roli i roślin. Materiały pomocnicze do ćwiczeń*, ed. W. Roszak. PWN Warsaw. 1997.
[49] Crop rotation is a term wider than the rotation, the rotation is applied to the fields and planned for future years. In other words, crop rotation is rotation in space and time (Połosz 1998).
[50] Kuś J., *Rola zmianowania roślin we współczesnym rolnictwie*, Institute of Soil Science and Plant Cultivation, Puławy 1995.
[51] Starczewski J., *Uprawa roli i roślin. cz. II. Rośliny uprawy polowej. Technologie uprawy roli i roślin*, ed. J. Starczewskiego. Akademia Podlaska, Siedlce 2006.

According to J.St. Zegar, *sustainable agriculture requires the use of farming practices which do not violate environmental sustainability, provide economic benefits and promote social development, and in the case of agricultural holdings, the fundamental issue is meeting threshold environmental values, or more precisely the component of maintaining soil fertility − a permanent capacity of the soil to produce biomass*[52]. According to this thesis, the study found the farms using crop rotation of Norfolk type to be environmentally sustainable.

The study isolated and analyzed farms characterized by the use of Norfolk crop rotation. The system consists in dividing cultivated area to four fields and growing plants on them in a four-year rotation. Classic four-field was created in England in the eighteenth century and concerned the cultivation of such plants as: roots, spring cereals + undersown crops, fodder, followed by winter crops. Application of the Norfolk system is considered to be the most preferred because it maintains soil at high agricultural efficiency and usefulness. Structure of crops in this system was developed by the Institute of Soil Science and Plant Cultivation State Research Institute (IUNG-PIB) and recommends a maximum of 50% of cereals, a minimum 25% of structure creating plants, i.e. pulses, fodder and up to 25% of root crops[53].

The primary empirical material used for the analysis of Norfolk farms is the data on holdings under observation by Polish FADN, which include units of economic size equal to or greater than 2 ESU[54] and at the same time producing a total of 90% of the gross margins (SGM)[55] in Poland. This sample is representative and includes more than 12 000 farms, so that one farm corresponds to more than 60 farms in Poland[56].

[52] Zegar J.St. (ed.), *Z badań nad rolnictwem społecznie zrównoważonym (8). Zrównoważenie polskiego rolnictwa w świetle danych statystyki publicznej*, Report of the Multiannual Programme No. 161, IAFE-NRI, Warsaw 2009, p. 15 and 18.

[53] Fotyma M., *Problematyka rolnictwa zrównoważonego.* Newsletter of the Institute of Soil Science and Plant Cultivation, Puławy 2000, p. 14.

[54] European Size Unit (ESU) - this parameter is used to determine the economic size of a farm established on the basis of standard gross margins. One ESU is equivalent to EUR 1200 (Goraj L., et al. 2010).

[55] Standard gross margin is a surplus of production value in a given agricultural activity over the value of direct costs in average conditions of production in a given region (Goraj L. et al., 2010).

[56] Goraj L. et al., *Wyniki standardowe uzyskane przez gospodarstwa rolne uczestniczące w Polskim FADN w 2009 roku. Część I. Wyniki standardowe,* Warsaw 2010.

The criterion for the selection of farms to the research sample was the crop structure similar to that recommended in the Norfolk rotation. FADN data do not register whether the farmer applies rotation on a particular plot of land, because there is no relationship between the data relating to the plots and the crops. However, for the purposes of the following study it was considered appropriate to use the assumptions of rationality and it was found that the number of crops may be the basis to infer about the use of crop rotation in these farms.

Analyzed group was isolated on the basis of the following assumptions made by J.St. Zegar in the Multiannual Programme Report 161:

- crops on arable land − 100%;
- up to 60% of cereals[57] (including species of wheat, rye, barley, oats, triticale, mix cereals, buckwheat, millet, maize for grain, cereal and legumes mixtures for grain, other cereals);
- at least 20% of legumes and forage (plant species included: legumes for grain, i.e. edible legumes (including peas, beans, broad beans), legume fodder (including field peas, vetch, faba beans, sweet lupines), legume fodder for green matter, grass field for green matter, other fodder on arable land for green matter);
- up to 20% of roots and other (species included: roots − potato, sugar beet, fodder root crops (including fodder beet), industrial oil plants − rape and turnip rape, other oilseeds (including sunflower for grain, soybean, linseed), other industrial, vegetables and strawberries in rotation with agricultural crops, maize for green matter, other species not classified into the above groups.

These assumptions are basic criteria to be met in farms in environmental and production terms. Full criteria have been developed within the framework of the Multiannual Programme and presented in the work by J.St. Zegar and W. Wrzaszcz in Reports No. 11, 30, 59, 161. However, it was found that for the purposes of this study, the principle of approximation to the optimum will apply, and thus ultimately on this basis the selected farms were considered as environmentally sustainable.

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[57] According to J. Kuś, the allowable share of cereals in the structure should be no more than 66% and should not exceed 75% of the sown area.

Therefore, farms with the above structure of crops were considered "Norfolk farms", i.e. potentially sustainable in environmental terms, because of their importance for maintaining and restoring soil fertility. Other farms that do not meet these assumptions serve as comparative and are called: "other farms" or alternatively "conventional farms".

The analysis uses the data for specific groups, i.e. their proportion, area of agricultural land, average value of farm production, and data on the creation of standard gross margin. The data on the average farm income per 1 fully employed family member, the average amount of work expressed in AWU, serve as an indicator of economic sustainability. The analysis uses data on holdings where FADN accounting was conducted in four consecutive years, 2006-2009, which created a basis for conclusions. Isolating Norfolk and conventional farms allowed the use of a comparative analysis of their economic efficiency. The results of the analysis are presented in the form of tables and graphs.

3.1. Characteristics of the population of Norfolk farms

This chapter gives a presentation of holdings selected for the study from Polish FADN units according to the division into Norfolk and conventional farms in four consecutive years 2006-2009 covered by the analysis (Table 11). Number of farms selected for the study is constant and deliberate within the analyzed period and equals 8578 farms, because only in this way we could make note of the use of crop rotation on farms. The number of farms selected for the survey was also determined by the share of Norfolk farms in different types of production and ranges of economic potential.

Table 11. Sample population selected from the Polish FADN farms in 2006-2007

Description	2006	2007	2008	2009
Total number of holdings	8 578	8 578	8 578	8 578
Norfolk farms	172	275	314	329
Other farms	8 406	8 303	8 264	8 249

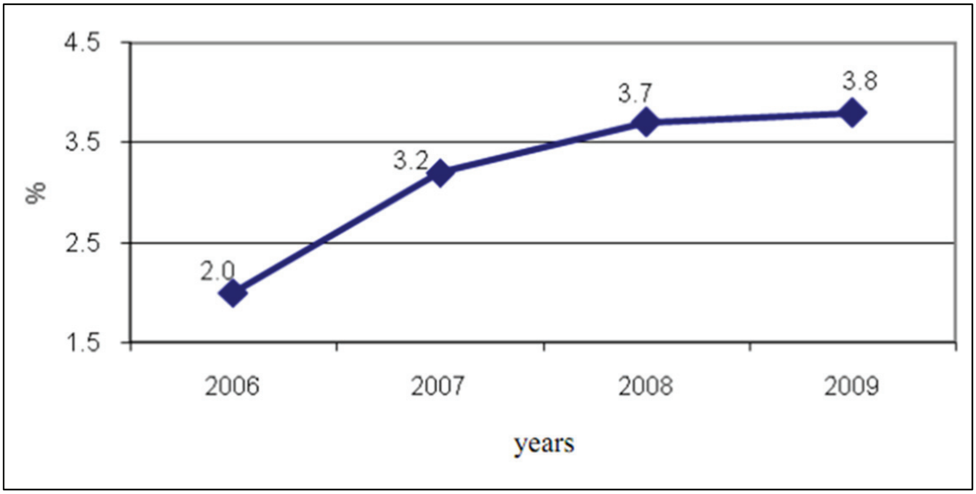
Source: own compilation based on the FADN data.

We followed the principle of excluding the farms in production types and ranges of economic size, in which there were no Norfolk farms. In view of the fact that Norfolk farms were present only in the type of “field crops”, “mixed” and “granivorous animals”[58] and in all economic ranges except from 40 to 100 ESU, the conventional holdings that were outside the set were not included in the study. It should also be noted that conventional farms outside the set of analysed holdings, according to the authors, are not able to requalify their production to meet the above assumptions regarding the rotation.

The data used in the analysis shows that although the number of Norfolk farms increased steadily over the period, it was still a relatively small number. In 2006-2009 the number of Norfolk farms increased by about 91%, and their share in the total analyzed FADN population increased nearly 2-fold (from 2 to 3.8%). This may prove the fact that farmers increasingly more often recognize the benefits of crop rotation on their farms.

[58] The type of field crops includes cereals, oilseeds and legumes, other field crops; horticultural and permanent field crops together; the granivorous animals type is for animals fed with concentrate feeds; the mixed type is for various animals, mainly fed in the grazing system and with concentrate feeds, and for field crops together with animal husbandry in the grazing system and different crops and animals together (Goraj L. et al., 2010).

Figure 11. Share of Norfolk farms in the analyzed sample of FADN farms

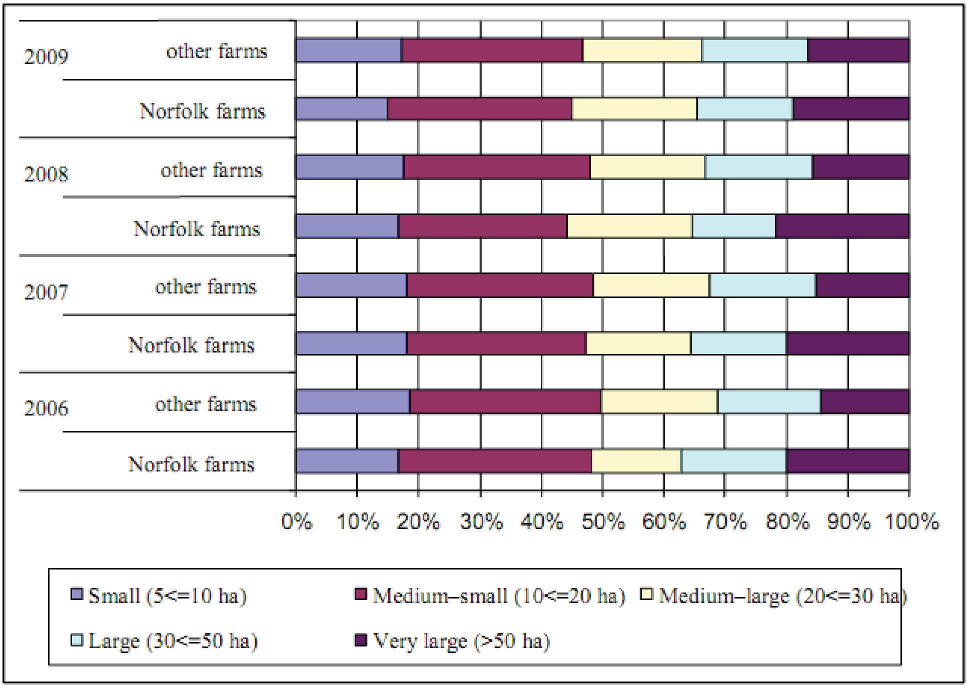


Source: own compilation based on the FADN data.

We analyzed the production potential of selected groups of farms, using agricultural land and labour inputs expressed in AWU.

The largest population of Norfolk farms has the highest share of agricultural land in the range of 10-20 ha, it constituted 31.4% in 2006, and in subsequent years this proportion has not changed significantly. The second largest share of farms in each area groups was the range of large farms with over 50 hectares of arable land − where the figure was almost 20%. In addition, the years 2006-2009 saw an increase in the percentage of relatively large farms (20-30 ha of agricultural land) from 14.5 to 20.4%, i.e. by 5.8 percentage points. While in the first year of the study the area with the second largest share in Norfolk farms was thee area of the largest farms, i.e. 50 hectares and above, in the last year of the area with the second largest share was the area in the range of 20-30 ha of agricultural land. The remaining farms, similar to Norfolk farms, were ultimately characterized by agricultural area in the range of 10-20 ha, and in the second place, the area of agricultural land in the range of 20-30 ha – this was about 19% in each of the analyzed years.

Figure 12. Distribution of farms by areas in %

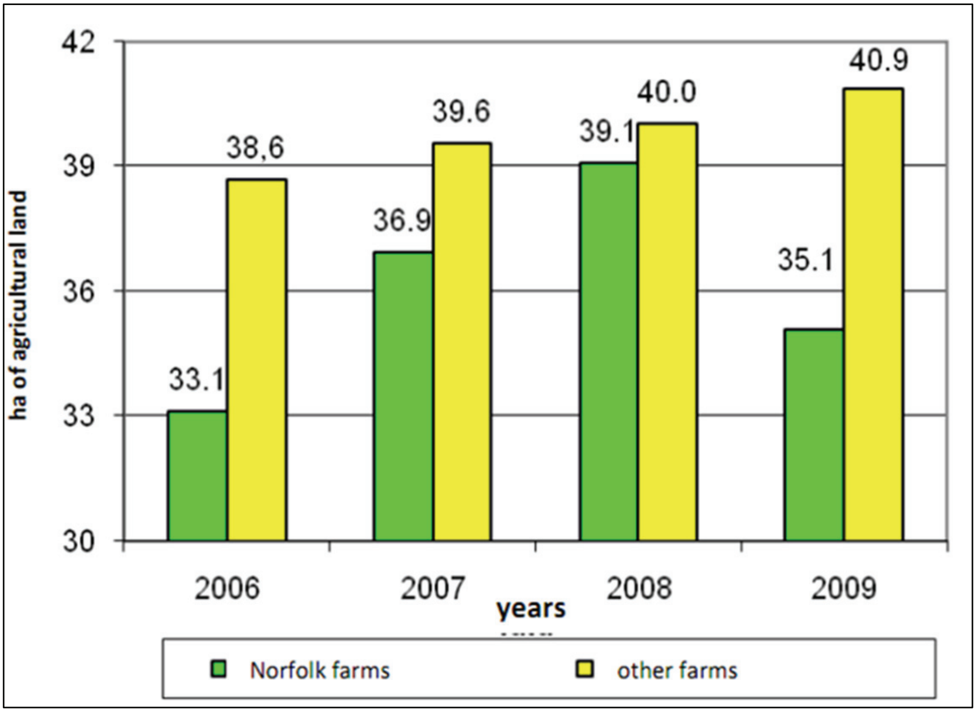


Source: own compilation based on the FADN data.

In summary, the biggest relative change in the number of Norfolk farms was observed in the group of farms with the area of 10-20 hectares and the area of over 50 hectares. Generally, the area structure of farm groups presented in the study was very similar in 2009.

Some slight changes in the average size of Norfolk farms were also the result of minor changes in the area structure of farms (Figure 13). In 2006-2009 the average area of Norfolk unit increased by less than 2 ha of agricultural land (from 33.1 to 35.1 ha, an increase of about 6 percentage points), but over the analyzed period showed large fluctuations. Therefore, the area of a Norfolk farm in 2007 increased by 11%, in the next year only by 6%, while in 2009 there was negative growth of 10%. The average area of other farms showed little growth and from the average area of agricultural land − 38.6 ha in 2006 gradually increased by 6% to 40.9 ha. Generally, during three analyzed years, the average area of the two groups of farms represented a countervailing trend, because although in 2006 the difference between the types of farms was 5.5 ha, in the following year, it was only 2.7 ha, and in 2008 only less than one hectare differentiated the farms. However, the last year included in the analysis diversified the average farm area to the level of 2006 (the difference was 5.8 ha).

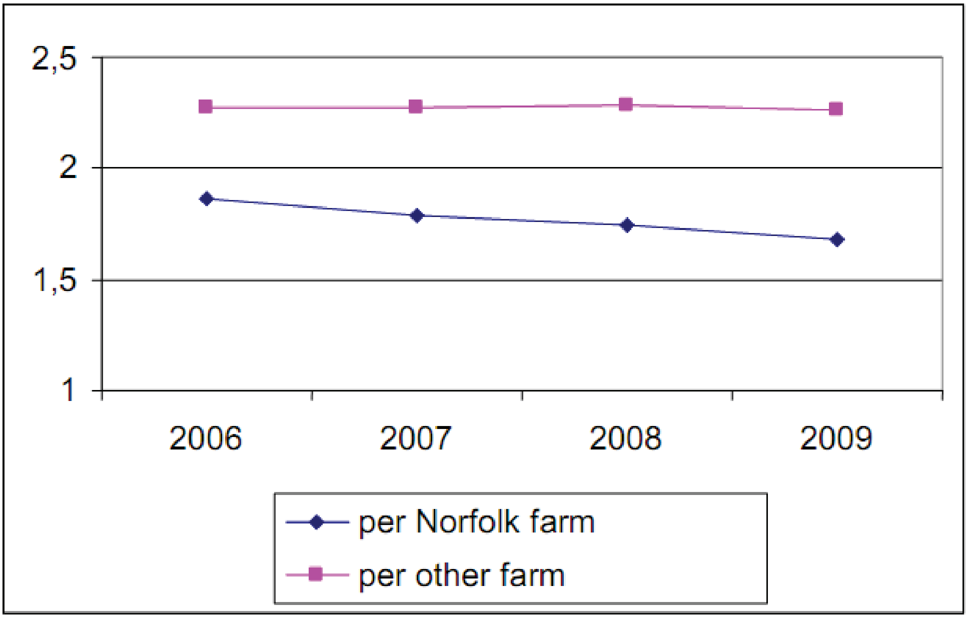
Figure 13. Average size of agricultural land in selected groups of farms in ha of agricultural land



Source: own elaboration, based on FADN data (sample includes holdings with more than 5 ha of agricultural land).

Regardless of the area structure of Norfolk farms, which turned out to be similar to that of conventional farms, the groups of farms were characterized by varied labour inputs. The study analyzed labour inputs in total and per 1 ha of agricultural land.

Figure 14. Average total labour inputs per one farm (in AWU[59])



Source: own compilation based on the FADN data.

Thus, the labour input equivalent to 1 AWU in Norfolk farms in 2009 consisted of 1.68 individual (household members), i.e. 34% less than in other farms in 2009. This can be explained by the fact that production of these farms was less labour intensive or more mechanized. Reduction in employment may also indicate improved overall management and growth of labour productivity in the analyzed Norfolk units.

In 2006-2009 the total labour inputs per farm in the set of Norfolk farms decreased by 9.5% (from 1.86 to 1.68 AWU per farm). It should be noted that labour inputs per conventional farm within the analyzed period remained at virtually the same level. However, labour inputs per 1 ha of agricultural land, both in other farms and in Norfolk farms remained at the same level – 0.06 AWU/ha of agricultural land.

[59] The labour input on farms is specified in AWU (Annual Work Unit), i.e. the conversion work units, where 1 AWU corresponds to 2200 hours of work a year. This parameter includes the own labour inputs of farm owners and their families and employees.

Similar labour inputs per hectare of agricultural land in these farms can be linked to an almost identical area structure in these farms. The diversity of farms in terms of labour inputs per farm may be explained by higher labour intensity of production in conventional farms due to the nature of this production (special sections), this is evidenced by the significant value of production achieved in the area group of 5-10 ha; it is more than five times higher.

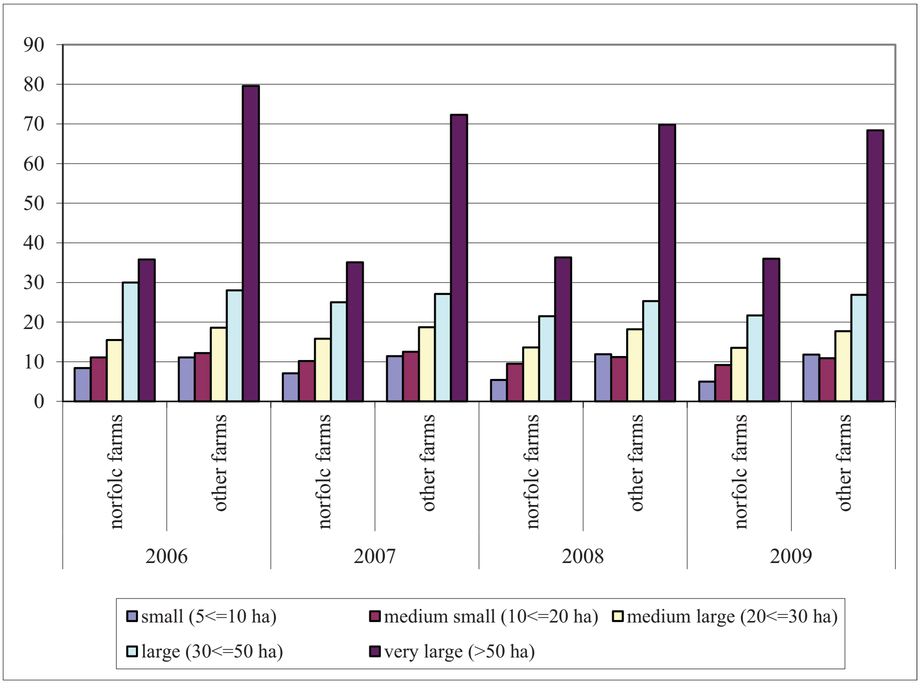
3.2. Economic potential and volume of production in Norfolk farms

For reference purposes we used the division of farms used in the EU countries, which is based on the economic size of farms. According to the FADN method used in 2004-2009, the total value of standard gross margins corresponding to all activities carried out in the farm is the basis for determining its economic size class (*Wyniki standardowe...* 2009). The economic size expressed in ESU units allows us to illustrate the overall result of farm activities, taking into account three components, namely: physical size, income from production and associated direct costs.

When comparing the economic power of farms based on the size of the area, one should note the fact that the value of economic strength is closely linked to the size of farms, both Norfolk and conventional. Average economic strength of Norfolk farms in 2009 was 16.5 ESU, and although it decreased by 15% compared to 2006, we still can define those holdings as competitive[60]. Other farms were characterized by average economic capacity at much higher level – 25 ESU and this ability was maintained at the same level throughout the analyzed period.

[60] For the classification to competitive and uncompetitive farms, see Multiannual Programme Report No. 132, p. 119.

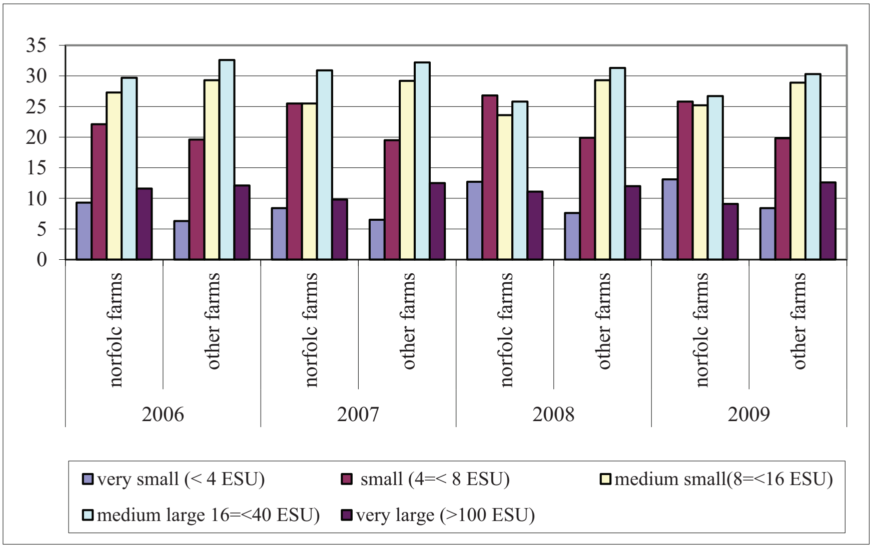
Figure 15. Differentiation of the average economic size of Norfolk farms and other farms in selected area groups in 2006-2009 in ESU



Source: own compilation based on the FADN data.

Within each area group, the capacity for competition – i.e. more than 16 ESU was reached mostly by farms above 20 ha. The greatest economic power was characteristic for conventional farms and Norfolk farms with area over 50 hectares − the strength was maintained at an average of 70 ESU for other farms and 35 ESU for Norfolk farms. This level was maintained throughout the analyzed period. It is an interesting observation that conventional farms have significantly higher economic potential in the smallest area group of 5-10 ha (in the last two years, the potential has been even twice as high as in Norfolk farms). This is probably related to the value of production, which is also a factor differentiating these two groups of farms in this particular range of area. This can be explained by the fact that farms derive higher revenues in relatively small farms through their specialization in vegetable production, protected cultivation, and production of flowers, while farms above 50 ha derive their profits more often as result of the economies of scale.

Figure 16. Density of farms in terms of economic potential



Source: own compilation based on the FADN data.

The average economic size of Norfolk farms in 2009 was 16.5 ESU and it was a level lower than the average for the whole set of analyzed farms (24.4 ESU), while the value of economic strength of other farms exceeded the average level for the sample. It should be noted that in 2009, 43% of other farms were the units with economic size of 16 or more ESU, i.e. those that can be considered as having a permanent competitive ability. However, among Norfolk farms only 36% exceeded this threshold. While the share of conventional farms in the group above 16 ESU remained at the same level throughout the analyzed period, the share of Norfolk farms gradually decreased from 41%, just above the threshold, to 36% in 2009.

Economic strength of the Norfolk group ranged from 16 to 40 ESU, this level has been maintained over the analyzed years except in 2008, when the economic strength of these farms was in the range of 4-8 ESU. The other farms were also generally characterized by economic strength in the range of 16-40 ESU. The share of farms with economic strength from 4 to 40 ESU was relatively evenly distributed between the lesser ranges and lasted for the period covered by the study, but the differences were evident in the extreme ranges, i.e. up to 4

ESU and over 100 ESU. While in the case of farms with low economic strength the difference between those groups was less than 5 percentage points in favour of farms using crop rotation, in the range of the strongest farms the proportions were reversed and the share of conventional farms in this group was higher; the difference was more than 3 percentage points.

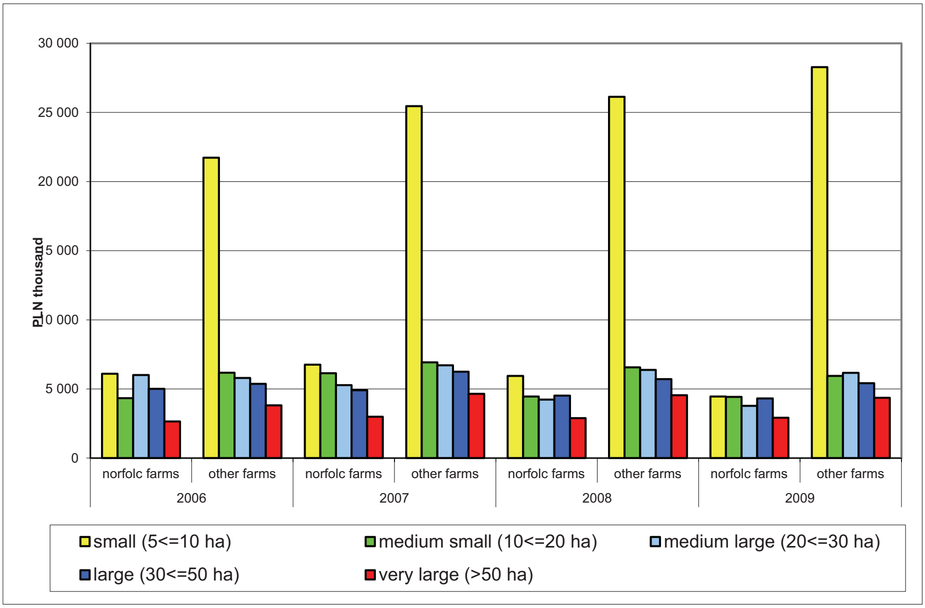
In terms of production capacity, the aim of each farm should be to minimize the use of production factors (resources) to achieve the maximum possible efficiency. This means the optimization of production effects, i.e. the situation where the producer when maximizing the results of production does not put more resources than it is necessary to achieve the effect size (Karwat-Woźniak, 2009).

This principle becomes important if we take into account the scarcity of resources in agriculture, especially the area of land used for agriculture. Another important issue is the context of reducing the negative impact of agriculture on the environment. Therefore, in order to achieve the desired effect size – the productivity, one should optimise utilisation of all factors of production (land, labour, capital) and at the same time limit the use of industrial inputs, which will minimize the negative effects on the environment.

In order to analyze the efficiency of inputs, and thus their relationship to the final effects, we used productivity indicators, such as labour efficiency, the value of production in terms of labour inputs and the value of agricultural production per area unit of agricultural land (land productivity). The study used the resulting main category of farms which is the total value of production. It includes: total value of crop production, animal production, and other production (Goraj L. et al., 2010).

Also, in terms of competitive ability, in order to obtain a satisfactory income, and thus the appropriate standard of living for farm families, it is important to include the value of farm production which is a main source of income for the farmer and his family.

Figure 17. Differentiation of the average value of agricultural production per 1 ha of agricultural land in Norfolk farms and other area ranges in 2006-2009 in PLN thousand

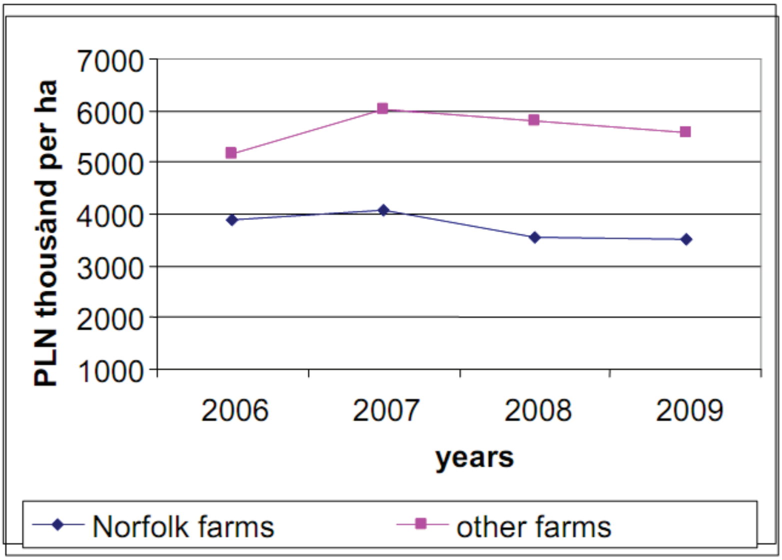


Source: own compilation based on the FADN data.

These groups differed significantly in terms of production value. Norfolk farms were characterized by almost two times lower average of this category compared to conventional farms. In the years covered by the study the difference between production values gradually increased from 55% in 2006 to 84% in 2009.

Figure 18 illustrates the diversity of agricultural production value in relation to the area of agricultural land in Norfolk farms and conventional farms.

Figure 18. Differentiation of the average value of agricultural production per 1 ha of agricultural land in Norfolk farms and other farms in 2006-2009 in PLN thousand



Source: own compilation based on the FADN data.

The analysis of land productivity shows that the use of production capacity in these groups was diverse. In 2006, the average production value of 1 ha of agricultural land in Norfolk farms was PLN 3.9 thousand, and the corresponding indicator for other farms was PLN 5.1 thousand, so the difference between the two groups was 34%, in 2009 the analogous indicator was also around 37%. Productivity of cultivated land in the whole period of analysis did not show a significant increase. The one increasing thing on the Figure is the distance between other farms and Norfolk farms in the area group of 5-10 ha with regard to land productivity as measured by production value per 1 ha of agricultural land. It can be assumed that such large differences in land productivity were due to the specific structure of crops in conventional farms. These are mainly special sectors, which are characteristic for this group of farms. It is worth pointing to the fact that the lowest value of production per 1 ha of agricultural land was characteristic of the largest farms – over 50 ha, it may be due to a more extensive way of farming in these farms. The lowest average value of production in the area group of over 50 hectares was achieved in Norfolk farms and it amounted to less than PLN 3 thousand per ha of agricultural land throughout the analyzed period, while in the case of other farms, the value of production in this period was around PLN 4.3 thousand per ha.

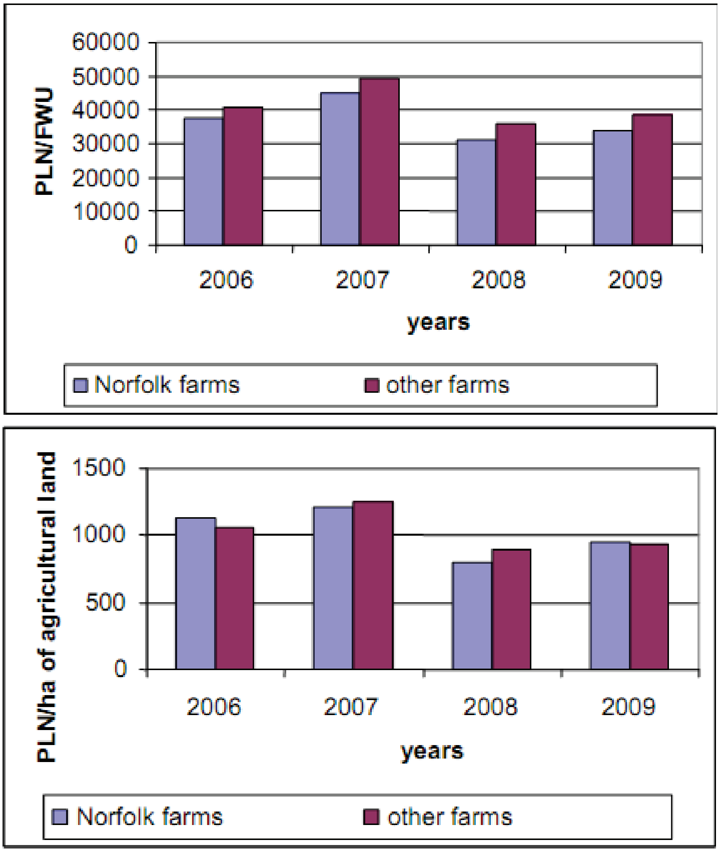
Decreasing trend in the production value in the case of Norfolk farms was already noticeable in 2008, when only the smallest holdings reached the value of almost PLN 6 thousand, while holdings from other area groups did not exceed PLN five thousand. In the last year of analysis, the value of manufactured products in Norfolk farms in all area categories did not exceed PLN 5 thousand from one hectare of agricultural land. In the case of conventional farms, the downward trend in the value of production per hectare of agricultural land was not so important.

3.3. Level of income and labour productivity in Norfolk farms

In order to determine the level of income of farms with different approaches to the use of agricultural production techniques, the research used the category of income per 1 member of the family fully employed on the farm and per 1 ha of agricultural land.

The level of agricultural income generally diversified the groups of farms, both in terms of family member fully employed on the farm, as well as per 1 ha of agricultural land.

Figure 19 and 20. Norfolk farms and other farms in relation to the average income of family farms per person fully employed on the farm (FWU[61]) and per 1 ha of agricultural land



Source: own compilation based on the FADN data.

As illustrated by Figures 19 and 20, the income per hectare of agricultural land in the two groups of farms in 2006 exceeded PLN 1000, in the next year increased for Norfolk farms by 7%, and in the case of conventional farms by 15%. 2008 brought a significant reduction in income among farms using crop rotation and among conventional units (respectively by 34% and 28%). In the last

[61] FWU – conversion work unit of work done by family members, i.e. persons working 2120 hours a year (Family Work Unit).

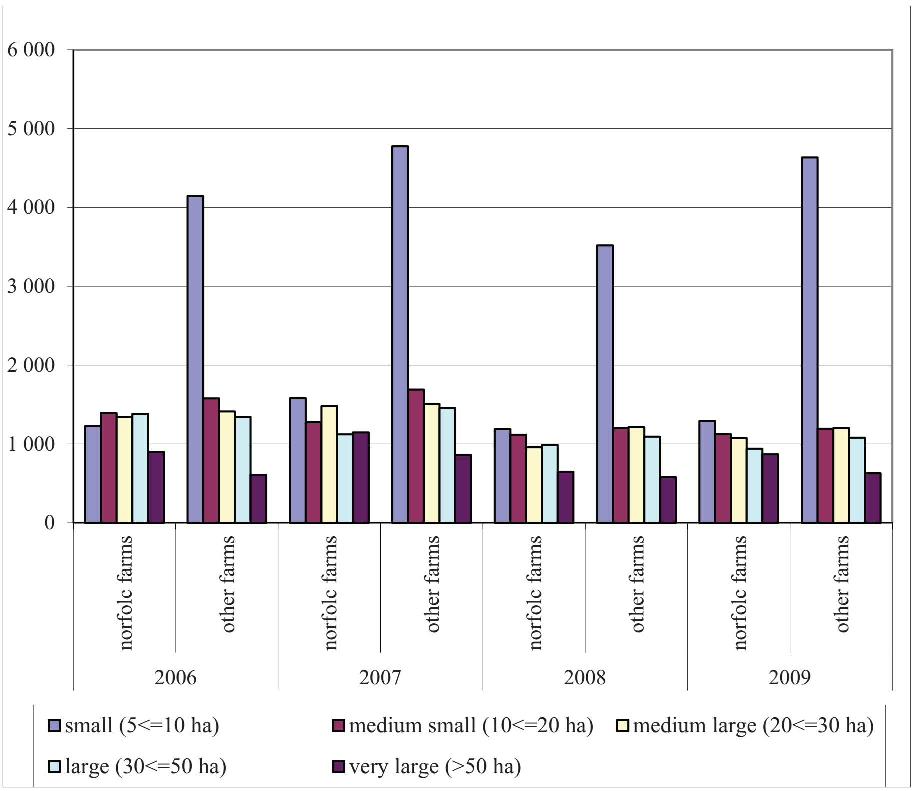
year of analysis there was, in turn, a significant increase in income in Norfolk farms, on average by 20%, while only by 5% in other farms. However, in both cases, the income per hectare of agricultural land did not reach the level of 2006.

In 2009, the average income in Norfolk farms per 1 fully employed family member amounted to PLN 33.5 thousand and was lower by 14% from the income achieved at the same time by fully employed family member in other farms (PLN 38.3 thousand). Analysis of the dynamics of income during the period shows a decline in income per fully employed family member, both in Norfolk farms and others farms. As compared to 2006, the income of Norfolk units per 1 fully employed family member in 2009 was on average lower by PLN 4 thousand and it was a relatively large drop in value, especially compared to other farms. In this group, the annual agricultural income per family member during the period decreased by only 6%, i.e. by PLN 2.4 thousand.

In 2006, the average income of Norfolk farms per fully employed family member was PLN 37.4 thousand. A similar indicator among other farms achieved the level of income higher by 9% than the one obtained in a set of farms using Norfolk rotation. Four years later, in 2009, this difference was more than 14%. This shows that these farms become increasingly diverse in terms of agricultural income. The level of agricultural income was diversified depending on the characteristics of the farm. These links can be explained by comparing the income from agricultural activities on farms of varying area. There is not only a great relationship between the area of cultivated land and the income, but also for other characteristics that determine the potential of farms and production efficiency. Direct payments to farmers also significantly affect these relationships.

Thus, as illustrated in Figure 21, the income per hectare of agricultural land, depending on the available agricultural area of these farms, is highly diversified. Particularly large disparities are in the group of the smallest farms with 5--10 ha of agricultural land. Here the difference between Norfolk farms and other farms is about PLN 3 thousand per ha to the detriment of farms using crop rotation. This is probably related to the structure of production in the group of other farms (special sections). Such large differences no longer occur in subsequent area groups. It should be noted that income from one ha of agricultural land in other area groups is on a similar level. Research has shown that holdings with large area of more than 50 ha are generally less profitable. Here income amounted to less than PLN 1 thousand per ha. This is probably related to more extensive production. Over the last two analyzed years, the income of Norfolk farms was visibly smaller in the next two area groups from 20 to 50 ha on average by 15% than the income in conventional farms in the same area group, but this situation was reversed in the largest farms where income of Norfolk farms was higher on average by 20-30%, and this rule applied to all investigated years.

Figure 21. Differences in the average income of family farms per person fully employed in Norfolk farms and other farms in selected area groups in 2006-2009, in PLN

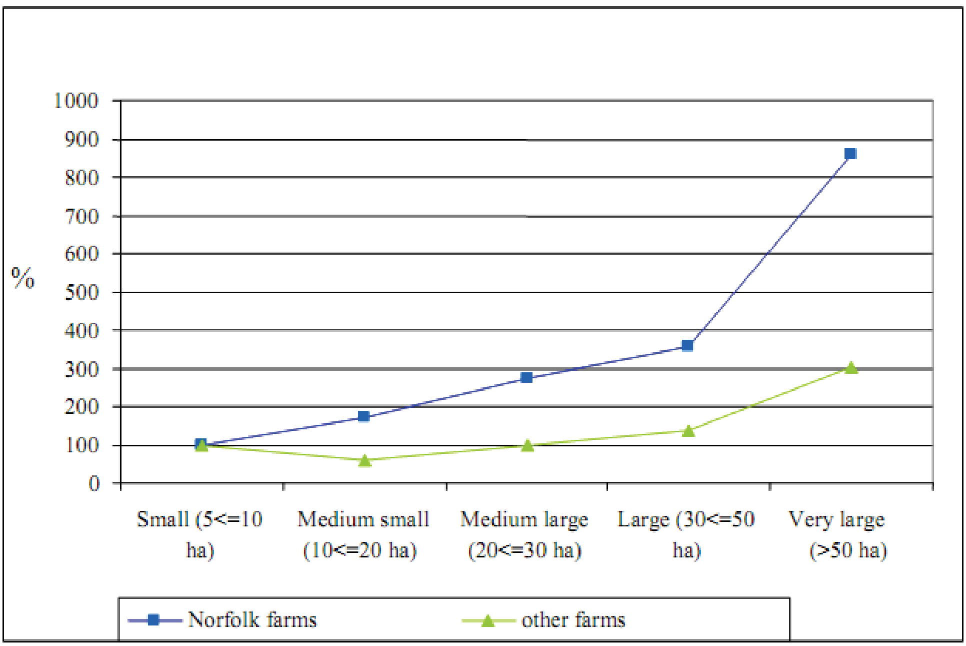


Source: own compilation based on the FADN data.

This would mean that the use of crop rotation is profitable only for large farms, i.e. over 50 ha and one should seek to increase the area of these farms in order to achieve greater profitability.

When comparing the value of agricultural income, depending on the area of cultivated land and taking as a reference the level of agricultural income received by the smallest farms (with an area from 5 to 10 ha), it can be stated that in 2009 (as in previous years) relatively the lowest income from agricultural business were received by other farms with area from 10 to 20 ha (Figure 22). This income was on average lower than in previous years by 20-30%.

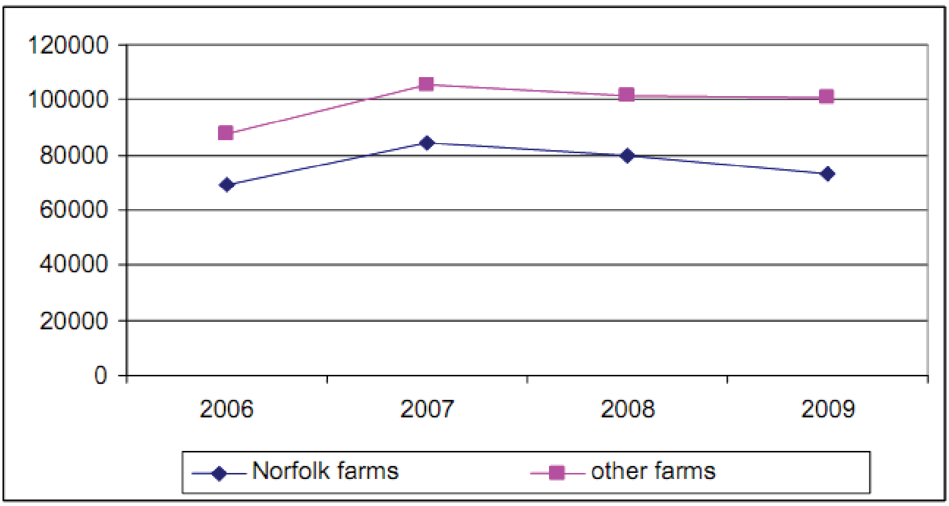
Figure 22. Differences in the average income of family farms per family member fully employed in Norfolk farms and other farms in selected area groups (group of 5-10 ha = 100) in 2009



Source: own compilation based on the FADN data.

Norfolk farms in each area group received more income than in the smallest area group and it grew much faster than in other farms. Norfolk farms with 20-30 ha showed more than 2.5-fold increase in income per family member fully employed on the farm, while other farms did not record any growth during that time. Norfolk farms from the largest area group (50 ha and more) achieved particularly high (more than 8-fold) advantage over other units of the group 5-10 ha of agricultural land in terms of income earned per one family member fully employed on the farm. Differences in income presented in this way show the importance of farm size in shaping agricultural income in these groups.

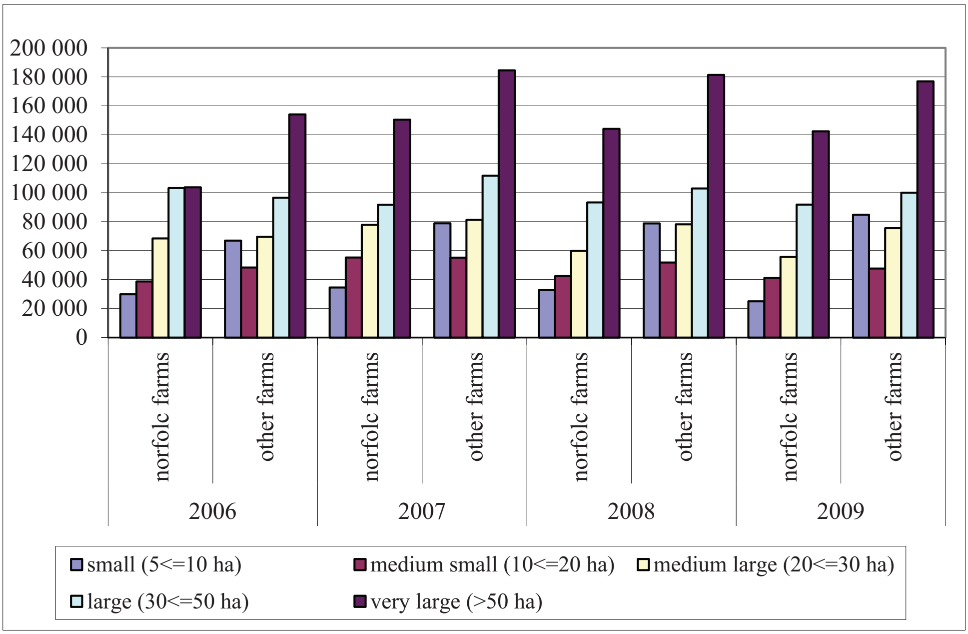
Figure 23. Differentiation of the average value of agricultural production per 1 AWU in Norfolk farms and other farms in 2006-2009 in PLN thousand per AWU



Source: own compilation based on the FADN data.

The labour productivity analysis shows that in 2006 the average value of agricultural production per 1 AWU in Norfolk farms was PLN 69 thousand. At the same time, the comparable index for other farms was 27% higher than in Norfolk farms (PLN 89 thousand per 1 AWU). A similar difference in 2009 was 37%, therefore the difference worsened by 10 percentage points with the loss of Norfolk farms. A feature common to these groups of farms was the relatively high labour productivity in large farms above 30 ha of agricultural land. Diversifying feature of both these groups of farms was the level of labour productivity in small farms (5-10 ha); the difference between the productivity of small farms in was more than twice, even three times in 2009 in favour of conventional farms (Figure 23). Performance differentiation between small farms, as well as a relatively higher productivity in large farms remained throughout the period of analysis.

Figure 24. Differences in the average agricultural production per 1 AWU in Norfolk farms and other farms in 2006-2009 in PLN thousand in selected area groups



Source: own compilation based on the FADN data.

A comparison of changes in the productivity of land and labour in these groups of farms shows that both the use of labour resources and the land productivity in other units were relatively higher. However, the analysis of these two indicators in each area group showed that the land productivity was more equal among the two groups of farms, with the exception, of course, for small farms from 5 to 10 ha in the case of conventional farms, and labour productivity showed a large variation according to the area of farms.

3.4. Directions of specialization of Norfolk farms

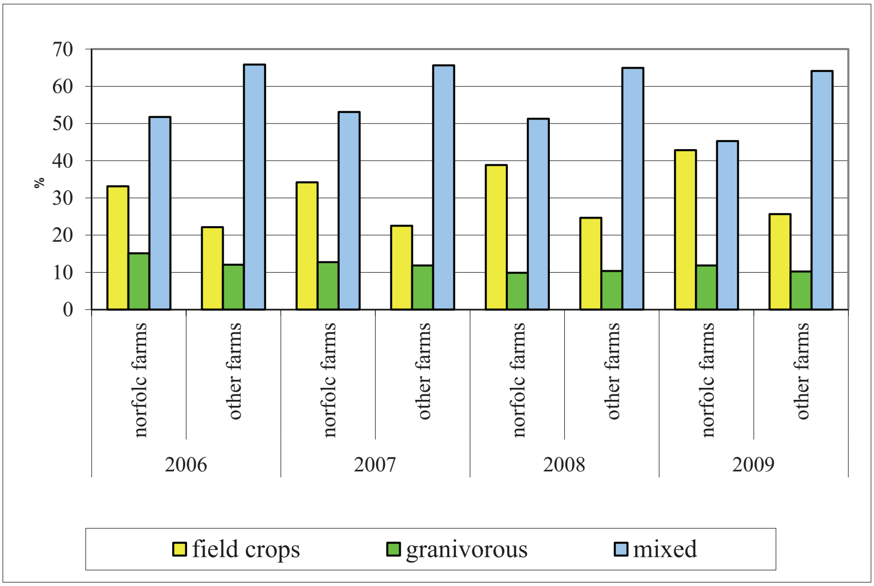
Another classification used for the comparative analysis of Norfolk farms and other farms is the general agricultural typology[62]. The crucial element of classification is the proportion of standard gross margin in each activity in the total SGM of the holding (Augustyńska-Grzymek 2000). Agricultural type presents the production system of the farm.

Because of the agricultural types, the surveyed farms were included in three types, i.e. "field crops", "granivorous animals" and "mixed type". In other types of production there were no farms using Norfolk rotation. This analysis showed that the groups of farms were significantly different in terms of types of production.

Both the Norfolk farms and other farms can be considered as multidirectional as they mainly specialized in mixed type. In the case of conventional farms, their proportion in mixed farms in 2009 was over 64% and this state was maintained for all analyzed years. According to calculations, every second Norfolk farm was of mixed type until 2009, when the proportion of mixed-type farms levelled with the proportion of farms of the field type (Figure 25). The share of these two types in Norfolk farms stood at over 40%. Farms of the seed eating animals type are characterized by a similar level of about 12% in each surveyed group and their share did not change much during the period.

[62] In this paper, the directions of farm specializations correspond to production types according to FADN typology.

Figure 25. Proportion of Norfolk farms and other farms according to production lines in different years

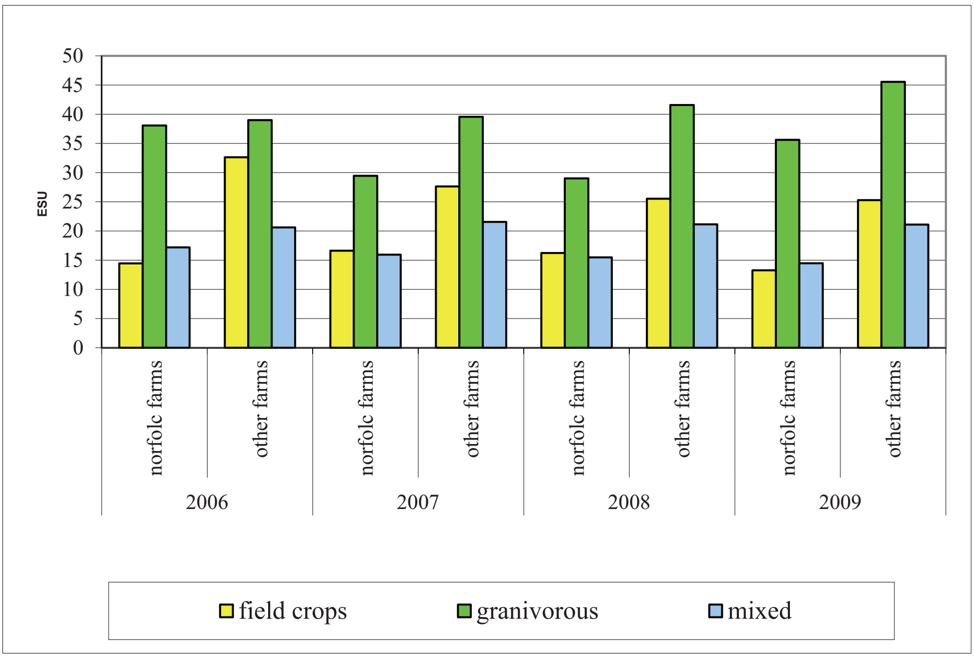


Source: own compilation based on the FADN data.

Economic strength of farms according to agricultural type is the greatest in the case of farm-type "granivorous animals" and oscillates around 30-40 ESU in both groups of farms. In the case of other farms, the economic strength of these farms is systematically increasing. Farms of the type “granivorous animals”, despite the fact that they are represented by the smallest number of both Norfolk and other farms, have the highest value of production per hectare of agricultural land (PLN 8.5 thousand per ha – Norfolk farms, PLN 13.6 thousand per ha − conventional farms) and the highest income per ha (respectively PLN 1.7 thousand per ha and PLN 2.3 thousand per ha). These figures relate to 2009, but in earlier years they did not change significantly.

Figure 26 shows a dependence regarding the economic strength of the farms, namely the declining economic strength of both Norfolk and other farms in the type of field crops. In the case of Norfolk farms it was reduced on average from 14.5 to 13.3 ESU, while in case of other farms it declined from 32.6 ESU and to 25.2 ESU in 2009. With regard to the economic strength of mixed farms, it is not subject to significant changes and remains at the level for the Norfolk farms − 16 ESU, and for other farms − 21 ESU. The dependence of the economic strength on the average value of production per hectare of agricultural land obtained in different production types of Norfolk and other farms may explain this relationship. The changes taking place in the dominance of different production types in each year can be linked to economic trends in agriculture.

Figure 26. Distribution of farms by lines of production
and the average economic size



Source: own compilation based on the FADN data.

Analyzing the average income per fully employed family member, one can see that in 2006 the most profitable was production of animals fed with concentrate feeds where income in both groups exceeded PLN 50 thousand. In the following year, the distribution of income changed and it turned out that they the most profitable were the farms of the type "field crops". This change related to both populations − the average income per person fully employed on the farm for both groups was around PLN 70 thousand. In 2008, there was another change in the profitability of production and then only family members from other farms in the type of "granivorous animals" received income over PLN 56 thousand. This group increased their income in the final year of the study to the level of PLN 76 thousand, and family members from Norfolk farms gained in this specialization the income of PLN 57 thousand.

*   *
*

This chapter presents the results of the study carried out on a sample of Polish FADN farms. The sample was divided into two populations of farms. The first one, called "Norfolk farms", represented a group of farms that meet the criterion of environmental sustainability, namely, increasing soil fertility, preventing soil erosion and loss of nutrients. The second group consisted of farms that do not meet these assumptions, i.e. "other farms" interchangeably referred to as "conventional farms".

The above-described characteristics of farms provided information about the significant diversity of monitored farms in terms of both, the average size of farms and their economic size, as well as the level of income in these farms.

Norfolk farms had a small share in a sample of farms − a mere 3.8% in 2009, but a positive development was the fact that their proportion had a positive growth in the years covered by the study. This would mean that the importance of these farms in Polish agriculture is gradually increasing.

As regards the area structure of Norfolk farms compared to conventional farms, it is convergent and shaped in the range of 10-20 ha (about 30% in both populations). The average size of agricultural land in Norfolk farms was 35.1 ha and in conventional farms − 40.9 ha. During the study period, there were no particularly significant changes in the average area of agricultural land in these farms. Due to the fact that there were no significant differences in terms of area between the two groups, it should be considered that Norfolk holdings as large as other farms.

Norfolk farms stood out in terms of labour inputs on farms. Labour input in 2009 was 1.68 of an individual (family members) per 1 AWU and it was about 34% less than in the other holdings in 2009. In addition, it is worth noting that labour inputs exhibited a downward trend within the period. This regularity can be considered beneficial because it points to an increase in labour productivity in Norfolk units.

Profitability of agriculture diversified significantly both these populations due to the separation of income per family member fully employed on the farm − the difference was almost PLN 5 thousand. As studies have shown for 2006--2009, the income gap between them is increasing. Linking income and the size of agricultural land in different area ranges revealed that the Norfolk farms are characterized by lower profitability than conventional farms, and the smallest differences can be noted in farms with area of 10-20 ha, and the largest in the group of 5-10 ha (special sections). The only size in which the income of Norfolk farms is higher than the income of other farms is the area of the largest farms above 50 ha. Unfortunately, this is a fairly low income, compared to those achieved in other groups (less than PLN 1000).

A characteristic feature of both groups of farms was their economic strength of 16 ESU reached for above 20 ha of agricultural land. The greatest economic strength was demonstrated by the largest farms − those over 50 hectares (Norfolk − 35 ESU, other − 70 ESU). It is worth mentioning that the threshold of 16 ESU, demonstrating competitiveness, was exceeded by only 36% of farms using crop rotation, and 43% of other farms.

Analysing the production value of these holdings, it is worth noting that the farms differed greatly in terms of the resulting value of production, and this deepened throughout the analyzed period. The difference in 2009 was 84%. As regards the productivity of these farms, i.e. the production per 1 ha of agricultural land, it was also diversified among the surveyed farms. The average value of production from 1 ha of agricultural land for farms using crop rotation in 2009 was lower by 37% than the corresponding ratio in the other farms. Also the labour productivity proved to be potentially detrimental to environmentally sustainable farms − the difference was also 37% in 2009.

As for specialization, the Norfolk farms mainly specialize recently in two directions, field crops and mixed type, whereas conventional farms specialize in the mixed type. The type of granivorous animals, despite the favourable characteristics (the greatest economic strength, value of production and income) is not popular among surveyed farms.

In conclusion, the studies show that potentially environmentally sustainable farms, i.e. those using Norfolk crop rotation system, are economically inefficient, with lower income and lower productivity. Due to the benefits to the environment they should be specially rewarded so their proportion in the structure of Polish agriculture can continue to grow.

Summary and Conclusions

Comprehensive assessment of sustainability of agriculture involves a number of elements related to economic, environmental and social issues. The scope of such assessment has a dynamic nature and depends, among other things, on the functions assigned to farms and the entire agricultural sector. New challenges for agriculture cannot however undermine its main task, which is to ensure food security (and safety).

The key parameter concerning the sustainability of agriculture, is therefore the level of productivity in terms of raw materials from the long-term perspective. Maintenance of productive capacity for the future generation combined with a positive impact on the environment reflects here the degree of sustainability of the farms in the environmental sphere. Economic sustainability, in turn, corresponds to the efficient use of agricultural resources in the appropriate size of agricultural production and generation of satisfactory farm income. Similarly, social sustainability refers to the efficient use of rural resources, especially labor, which is crucial for local communities and social balance. The diversity of farms is regarded as one of the elements of sustainable agriculture. Farms are characterized by different levels of resources and productive capacity. Therefore optimizing the organization of production on farm level can effectively fulfill often conflicting tasks for agriculture sector. Assessment of total productivity of the various forms of agricultural holdings thus corresponds to the optimal, from the point of view of society, allocation of resources to different production types.

Broadly understood sustainable development includes the issue of security of energy supply and renewable nature of its sources. Challenge of balancing the energy sector and a high potential for agriculture in the production of renewable energy sources resulted in the inclusion of energy security to the pool of tasks assigned to agriculture. The synergistic nature of this cooperation has led to the rapid development of biomass production for energy purposes, however the comprehensive assessment of the productivity and effectiveness of this activity is uncertain.

Quoted in the paper studies concerned with the interaction between agricultural production for food purposes and for energy purposes, pointed to the limited involvement of agricultural resources to improve energy security, especially on a global scale. The dynamic development of biofuel production on the basis of crops traditionally used for food production affects the strong rise in prices of raw materials for food production. Long-term analysis shows that the high rate of development of biofuel production was primarily driven by increase in yields of corn. On the other hand high prices of fossil fuels have increased the interest in investments in the biofuels sector and the dynamic growth of the production of bioethanol. As a result the strong rise in prices of agricultural products led to a decline in the profitability of the production of bioethanol. Among key determinants of the rapid development of the biofuels market appears to be a policy that supports this type of production and high fossil fuel prices. As a result, biofuel support policies can be responsible for strong increase of agriculture production prices while agricultural resources were used for bioethanol production. Namely the consequence of increased corn prices were rising prices of wheat as a complementary product for corn. The effectiveness of first-generation biofuels production is therefore justified by dynamic increase in corn yields and on the other hand − high prices of fossil fuels.

Rapid growth of the biofuel sector and expiring dynamics of crops yield used for energy production have led to a sharp increase in food prices. The expected increase in demand for raw materials for food production is enhanced by inefficiencies in the production of biofuels. It is expected that diminishing growth yields will be observed despite the growing prices of food. This indicates the need to increase investment in research and the search for more efficient technologies for agricultural production. On the other hand the expected growth of food prices is associated with an increase in demand for food in India and livestock products in China.

Improvement of balance between food and energy production with the use of agriculture resources is associated with plants dedicated to the production of biomass for energy purposes and utilization of marginal soils.

In the case of Polish agriculture the area of energy plants production is limited by environmental conditions. Quoted studies results indicate that the cultivation of energy crops have positive impact on the process of carbon sequestration in the soil, but this beneficial effect is dependent on climatic conditions, soil particle size and composition of the initial content of humus in the soil. Similarly, energy crops are characterized by high water requirements, which limits their use to areas with strong positive climatic water balance. Energy crops have a positively effect on biodiversity, however because of their physical dimension and large scale cultivation they have a negative impact on the value of the rural landscape. Unquestionably beneficial effects of energy crops is associated with the utilization of fallow land, which prevents the loss of agricultural land resources. The environmental constraints clearly shows that in Poland relatively small area of land can be used for the production of biomass for energy purposes.

Among the features of farms predisposed to the production of energy crops farms of mixed profile are to be pointed out. In this group of farm energy crops are the most competitive with conventional production lines. On the other hand due to higher labor inputs in the production of energy crops farm with excess labor are most suitable. In these farms growth in labor productivity is expected to be particularly strong.

The current market conditions, especially such as energy prices and the cost of production of biomass for energy purposes, result in the lack of sustainability of the production in the economic sphere. The need to include risk premiums in the subsidies proves economic inefficiency of the production. In extreme cases, forced regulations or subsidies to stimulate demand for biofuels will lead to a strong increase in prices mainly rapeseed and wheat. Paradoxically, it is expected that this will lead to increased competition between food production and the need to increase support for energy production. The increase in the competitiveness of the agricultural area will therefore increase on one hand, food prices, and on the other − support production for energy purposes. This contradicts the basic objectives of sustainable agriculture.

Weak sustainability of agricultural production for energy purposes means that the development of this direction is mainly dependent on political decisions and technological development. Initially, the development direction of agricultural production for energy purposes was treated as an integral part of agriculture as contributing to the activation of agriculture and rural areas. Optimistic assumptions about the possibilities to combine these two types of production contributed to setting ambitious targets to cover the energy demand of agriculture. The dynamic development of the biofuel sector has revealed its negative impact on the market of foods and doubts about the positive impact on the environmental and social sphere. This effectively means that there is a need to revise the strategy to promote energy production in agriculture, in particular the need for a comprehensive assessment of its impact on the sphere of ecological and economic investment.

Recent developments offer opportunities for the development of distributed energy systems – prosument type. Farms with a high demand for energy, and specializing in the production of vegetables, are the optimal target group for this type of project. Promoting the use for energy purposes of waste from agricultural production and the food industry do not compete with food production. A wide range of biomass conversion processes suitable to different forms of farms promotes the process of decentralization of the sector. Similarly, the adoption of mechanisms to support the diversification of energy sources will help to optimize the use of agricultural resources for energy production, including using technology directly using solar or wind power. However, it is believed that a relatively small number of farms will be involved in energy production in the face of growing demand for food commodities.

The sustainable practices of agricultural land cultivation are critical for Polish agriculture. However farms that practice Norfolk crop rotation are of lower productivity and incomes in comparison with conventional farms. In case of these farms energy crops have a limited potential to improve their productivity while they are characterized with lower labor input. Therefore energy production should be a chance for conventional farms.

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